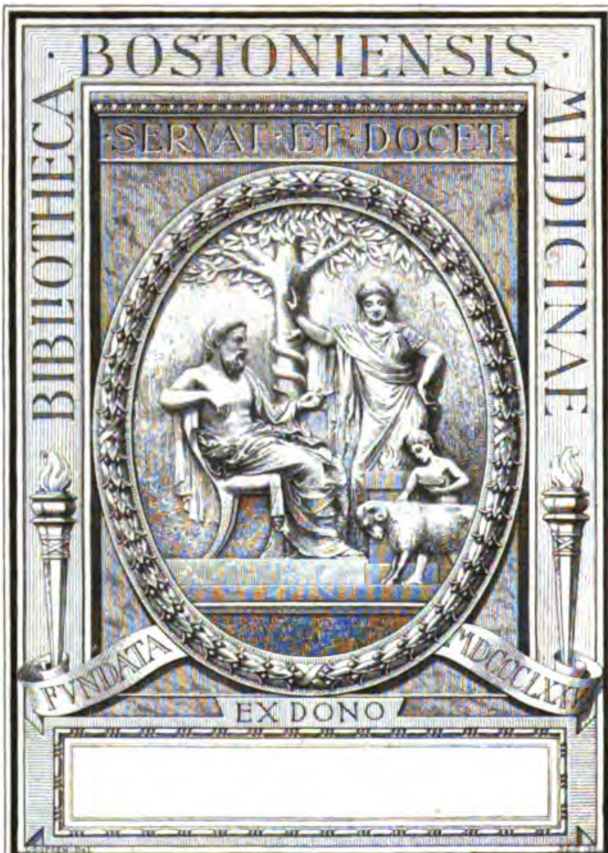
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PROCEEDINGS

OF

The American Association

FOR THE

ADVANCEMENT OF SCIENCE,

FIFTY-FIRST MEETING

HELD AT

PITTSBURG, PA.

JUNE-JULY, 1902

PUBLISHED BY THE PERMANENT SECRETARY

1902

EDITED BY

L. O. HOWARD,

Permanent Secretary.

WASHINGTON, D. C.
GIBSON BROS., PRINTERS AND BOOKBINDERS.
1902.

CONTENTS.

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(See Preliminary Announcement.)

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* For full membership of local committee, see the Preliminary Announcement of the Pittsburg meeting.

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From the Affiliated Societies.—American Chemical Society: F. W. Clarke, A. C. Hale; Geological Society of America: N. H. Winchell, H. L. Fairchild; Botanical Society of America: Arthur Hollick, H. M. Richards; Society for the Promotion of Agricultural Science: W. J. Beal, H. E. Alvord; American Microscopical Society: J. C. Smith, A. M. Holmes; American Psychological Association: E. C. Sanford; American Society of Naturalists: W. T. Sedgwick; Association of Economic Entomologists: A. D. Hopkins, C. L. Marlatt; American Anthropological Association: W. H. Holmes, Franz Boas.

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2. *Committee on Indexing Chemical Literature.*

H. CARRINGTON BOLTON, *Chairman*, F. W. CLARKE, H. W. WILEY, A. B. PRESCOTT, ALFRED TUCKERMAN.

3. *Committee on the Policy of the Association.*

THE PRESIDENT, *Chairman*, THE PERMANENT SECRETARY, THE TREASURER, C. S. MINOT, H. L. FAIRCHILD, JAMES LEWIS HOWE.

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5. *Committee on the Association Library.*

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6. *Committee on Anthropometric Measurements.*

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7. *Committee for the Collection of Information Relative to Forestry.*

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8. *Committee on the Quantitative Study of Biological Variation.*

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[1] All Committees are expected to present their reports to the COUNCIL not later than the third day of the meeting. Committees sending their reports to the Permanent Secretary one month before a meeting can have them printed for use at the meeting.

11. *Committee on the Teaching of Anthropology in America.*

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12. *Committee on the Relations of the Journal Science with the Association.*

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13. *Committee on the Relations of Plants and Climate.*

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15. *Committee on the Velocity of Light.*

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Meetings and Officers of the Association of American Geologists and Naturalists.

Meeting.	Date.	Place.	Chairman.	Secretary.	Assistant Secretary.	Treasurer.
1st	April 2, 1840,	Philadelphia,	Edw. Hitchcock,*	L. C. Beck,*		
2d	April 5, 1841,	Philadelphia,	Benj. Silliman,*	L. C. Beck,*	B. Silliman, Jr.,* C. B. Trego,*	
3d	April 25, 1842,	Boston,	S. G. Morton,*	C. T. Jackson,*	J. D. Whitney,* M. B. Williams,*	
4th	April 26, 1843,	Albany,	Henry D. Rogers,*	B. Silliman, Jr.,*		John Locke.*
5th	May 8, 1844,	Washington,	John Locke,*	B. Silliman, Jr.,* O. P. Hubbard,		Douglas Houghton.*
6th	April 30, 1845,	New Haven,	Wm. B. Rogers,*	B. Silliman, Jr.,* J. Law. Smith,*		Douglas Houghton.*
7th	Sept. 2, 1846,	New York,	C. T. Jackson,*	B. Silliman, Jr.,*		E. C. Herrick.*
8th	Sept. 20, 1847,	Boston,	Wm. B. Rogers,*†	Jeffries Wyman,*		B. Silliman, Jr.*

* Deceased.

† Professor Rogers, as chairman of this last meeting, called the first meeting of the new Association to order and presided until it was fully organized by the adoption of a constitution. As he was thus the first presiding officer of the new Association, it was directed at the Hartford meeting that his name be placed at the head of the Past Presidents of the American Association for the Advancement of Science.

Meetings	Place	Date	Members in attendance	Number of members
1	Philadelphia	Sept. 20, 1848	?	461
2	Cambridge	Aug. 14, 1849	?	540
3	Charleston	Mar. 12, 1850	?	622
4	New Haven	Aug. 19, 1850	?	704
5	Cincinnati	May 5, 1851	87	800
6	Albany	Aug. 19, 1851	194	769
7	Cleveland	July 28, 1853	?	940
8	Washington	April 26, 1854	168	1004
9	Providence	Aug. 15, 1855	166	605
10	2d Albany	Aug. 20, 1856	381	722
11	Montreal	Aug. 12, 1857	351	946
12	Baltimore	April 28, 1858	190	962
13	Springfield	Aug. 3, 1859	190	862
14	Newport	Aug. 1, 1860	135	644
15	Buffalo	Aug. 15, 1866	79	637
16	Burlington	Aug. 21, 1867	73	415
17	Chicago	Aug. 5, 1868	259	686
18	Salem	Aug. 18, 1869	244	511
19	Troy	Aug. 17, 1870	188	536
20	Indianapolis	Aug. 16, 1871	196	668
21	Dubuque	Aug. 15, 1872	164	610
22	Portland	Aug. 20, 1873	195	670
23	Hartford	Aug. 12, 1874	224	722
24	Detroit	Aug. 11, 1875	165	807
25	2d Buffalo	Aug. 23, 1876	215	867
26	Nashville	Aug. 29, 1877	173	953
27	St. Louis	Aug. 21, 1878	134	962
28	Saratoga	Aug. 27, 1879	256	1030
29	Boston	Aug. 25, 1880	997	1555
30	2d Cincinnati	Aug. 17, 1881	500	1699
31	2d Montreal	Aug. 23, 1882	937	1922
32	Minneapolis	Aug. 15, 1883	328	2033
33	2d Philadelphia	Sept. 3, 1884	1261*	1981
34	Ann Arbor	Aug. 26, 1885	364	1956
35	3d Buffalo	Aug. 18, 1886	445	1886
36	New York	Aug. 10, 1887	729	1956
37	2d Cleveland	Aug. 14, 1888	342	1964
38	Toronto	Aug. 26, 1889	424	1952
39	2d Indianapolis	Aug. 19, 1890	364	1944
40	2d Washington	Aug. 19, 1891	653†	2054
41	Rochester	Aug. 17, 1892	456	2037
42	Madison	Aug. 17, 1893	290	1939
43	Brooklyn	Aug. 15, 1894	488	1802
44	2d Springfield	Aug. 28, 1895	368	1913
45	4th Buffalo	Aug. 24, 1896	333	1890
46	2d Detroit	Aug. 9, 1897	283‡	1782
47	2d Boston	Aug. 22, 1898	903	1729
48	Columbus	Aug. 21, 1899	353	1721
49	2d New York	June 25, 1900	434	1925
50	Denver	Aug. 24, 1901	311	2703
51	Pittsburg	June 28 to July 3, 1902.	435	3473

* Including 303 members of the British Association and 9 other foreign guests.

† Including 24 Foreign Honorary members for the meeting.

‡ Including 15 Foreign Honorary members and associates for the meeting.

Officers of the Meetings of the Association.

[The number before the name is that of the meeting; the year of the meeting follows the name; the asterisk after a name indicates that the member is deceased.]

PRESIDENTS.

1. Wm. B. Rogers,*. 1848. / W. C. Redfield,* 1848.
2. Joseph Henry,* 1849.
3. A. D. Bache,* March meeting, 1850, in the absence of Joseph Henry.*
4. August meeting, 1850.
5. May meeting, 1851.
6. Louis Agassiz,* August meeting, 1851.
   (No meeting in 1852.)
7. Benjamin Pierce,* 1853.
8. James D. Dana,* 1854.
9. John Torrey,* 1855.
10. James Hall,* 1856.
11. Alexis Caswell,* 1857, in place of J. W. Bailey,* deceased. 1858, in the absence of Jeffries Wyman.*
12.
13. Stephen Alexander,* 1859.
14. Isaac Lea,* 1860.
    (No meetings for 1861–65.)
15. F. A. P. Barnard,* 1866.
16. J. S. Newberry,* 1867.
17. B. A. Gould,* 1868.
18. J. W. Foster,* 1869.
19. T. Sterry Hunt,* 1870, in the absence of Wm. Chauvenet.*
20. Asa Gray,* 1871.
21. J. Lawrence Smith,* 1872.
22. Joseph Lovering,* 1873.
23. J. L. LeConte,* 1874.
24. J. E. Hilgard,* 1875.
25. William B. Rogers,* 1876.
26. Simon Newcomb, 1877.
27. O. C. Marsh,* 1878.
28. G. F. Barker, 1879.
29. Lewis H. Morgan,* 1880.
30. G. J. Brush, 1881.
31. J. W. Dawson, 1882.
32. C. A. Young, 1883.
33. J. P. Lesley, 1884.
34. H. A. Newton,* 1885.
35. Edward S. Morse, 1886.
36. S. P. Langley, 1887.
37. J. W. Powell, 1888.
38. T. C. Mendenhall, 1889.
39. G. Lincoln Goodale, 1890.
40. Albert B. Prescott, 1891.
41. Joseph LeConte,* 1892.
42. William Harkness, 1893.
43. Daniel G. Brinton,* 1894.
44. E. W. Morley, 1895.
45. Edward D. Cope,* 1896. Theodore Gill, as senior vice-president acted after the death of Prof. Cope.
46. Wolcott Gibbs, 1897, absent. W J McGee, Acting President.
47. F. W. Putnam, 1898.
48. Edward Orton,* 1899. Grove K. Gilbert, elected by the General Committee December, 1899, to fill the vacancy caused by the death of Prof. Orton.
49. R. S. Woodward, 1900.
50. C. S. Minot, 1901.
51. Asaph Hall, 1902.
52. Ira Remsen, 1903.

VICE-PRESIDENTS.

There were no Vice-Presidents until the 11th meeting when there was a single Vice-President for each meeting. At the 24th meeting, the Association met in Sections A and B, each presided over by a Vice-President. At the 31st meeting nine sections were organized, each with a Vice-President as its presiding officer. In 1886 Section G (Microscopy) was given up. In 1892, Section F was divided into F, Zoology; G, Botany.

1857–1874.

11. Alexis Caswell,* 1857, acted as President.
12. John E. Holbrook,* 1858, not present.
13. Edward Hitchcock,* 1859.
14. B. A. Gould,* 1860.
15. B. A. Gould,* 1866, in the absence of R. W. Gibbes.
16. Wolcott Gibbs, 1867.
17. Chas. Whittlesey,* 1868.
18. Ogden N. Rood, 1869.
19. T. Sterry Hunt,* 1870, acted as President.
20. G. F. Barker, 1871.
21. Alex. Winchell,* 1872.
22. A. H. Worthen,* 1873, not present.
23. C. S. Lyman,* 1874.

1875–1881.

Section A.—Mathematics, Physics, and Chemistry.

24. H. A. Newton,* 1875.
25. C. A. Young, 1876.
26. R. H. Thurston, 1877, in the absence of E. C. Pickering.
27. R. H. Thurston, 1878.
28. S. P. Langley, 1879.
29. Asaph Hall, 1880.
30. Wm. Harkness, 1881, in the absence of A. M. Mayer.*

Section B.—Natural History.

24. J. W. Dawson, 1875.
25. Edward S. Morse, 1876.
26. O. C. Marsh,* 1877.
27. Aug. R. Grote, 1878.
28. J. W. Powell, 1879.
29. Alex. Agassiz, 1880.
30. Edward T. Cox, 1881, in the absence of George Engelmann.*

Chairmen of Subsections, 1875–1881.

Subsection of Chemistry.

24. S. W. Johnson, 1875.
25. G. F. Barker, 1876.
26. N. T. Lupton,* 1877.
27. F. W. Clarke, 1878.
28. F. W. Clarke, 1879, in the absence of Ira Remsen.
29. J. M. Ordway, 1880.
30. G. C. Caldwell, 1881, in the absence of W. R. Nichols.*

Subsection of Microscopy.

25. R. H. Ward, 1876.
26. R. H. Ward, 1877.
27. R. H. Ward, 1878, in the absence of G. S. Blackie.*
28. E. W. Morley, 1879.
29. S. A. Lattimore, 1880.
30. A. B. Hervey, 1881.

Subsection of Anthropology.

24. Lewis H. Morgan,* 1875.
25. Lewis H. Morgan,* 1876.
26. Daniel Wilson,* 1877, not present.
27. United with Section B.
28. Daniel Wilson,* 1879.
29. J. W. Powell, 1880.
30. Garrick Mallery,* 1881.

Subsection of Entomology.

30. J. G. Morris, *1881.

VICE-PRESIDENTS OF SECTIONS, 1882–

Section A.—Mathematics and Astronomy.

31. W. A. ROGERS,* 1882, in the absence of WM. HARKNESS.
32. W. A. ROGERS,* 1883.
33. H. T. EDDY, 1884.
34. WM. HARKNESS, 1885, in the absence of J. M. VAN VLECK.
35. J. W. GIBBS, 1886.
36. J. R. EASTMAN, 1887, in place of W. FERREL,* res'd.
37. ORMOND STONE, 1888.
38. R. S. WOODWARD, 1889.
39. S. C. CHANDLER, 1890.
40. E. W. HYDE, 1891.
41. J. R. EASTMAN, 1892.
42. C. L. DOOLITTLE, 1893.
43. { G. C. COMSTOCK, 1894. EDGAR FRISBY, 1894.
44. EDGAR FRISBY, 1895, in place of E. H. HOLDEN, resigned.
45. ALEX. MACFARLANE, 1896, in place of WM. E. STORY, resigned.
46. W. W. BEMAN, 1897.
47. E. E. BARNARD, 1898.
48. ALEX. MACFARLANE, 1899.
49. ASAPH HALL, JR., 1900.
50. JAMES MACMAHON, 1901.
51. G. W. HOUGH, 1902.
52. GEORGE BRUCE HALSTED, 1903.

Section B.—Physics.

31. T. C. MENDENHALL, 1882.
32. H. A. ROWLAND,* 1883.
33. J. TROWBRIDGE, 1884.
34. S. P. LANGLEY, 1885, in place of C. F. BRACKETT, res'd.
35. C. F. BRACKETT, 1886.
36. W. A. ANTHONY, 1887.
37. A. A. MICHELSON, 1888.
38. H. S. CARHART, 1889.
39. CLEVELAND ABBE, 1890.
40. F. E. NIPHER, 1891.
41. B. F. THOMAS, 1892.
42. E. L. NICHOLS, 1893.
43. WM. A. ROGERS, 1894.
44. W. LECONTE STEVENS, 1895.
45. CARL LEO MEES, 1896.
46. CARL BARUS, 1897.
47. F. P. WHITMAN, 1898.
48. ELIHU THOMSON, 1899.
49. ERNEST MERRITT, 1900.
50. D. B. BRACE, 1901.
51. W. S. FRANKLIN, 1902.
52. ERNEST F. NICHOLS, 1903.

Section C.—Chemistry.

31. H. C. BOLTON, 1882.
32. E. W. MORLEY, 1883.
33. J. W. LANGLEY, 1884.
34. N. T. LUPTON,* 1885, in the absence of W. R. NICHOLS.
35. H. W. WILEY, 1886.
36. A. B. PRESCOTT, 1887.
37. C. E. MUNROE, 1888.
38. W. L. DUDLEY, 1889.
39. R. B. WARDER, 1890.
40. R. C. KEDZIE, 1891.
41. ALFRED SPRINGER, 1892.
42. EDWARD HART, 1893.
43. T. H. NORTON, 1894.
44. WM. MCMURTRIE, 1895.
45. W. A. NOYES, 1896.
46. W. P. MASON, 1897.
47. EDGAR F. SMITH, 1898.
48. F. P. VENABLE, 1899.
49. JAS. LEWIS HOWE, 1900.
50. JOHN H. LONG, 1901.
51. H. A. WEBER, 1902.
52. CHARLES BASKERVILLE, 1903.

Section D.—Mechanical Science and Engineering.

31. W. P. TROWBRIDGE,* 1882.
32. DEVOLSON WOOD, 1883, absent, but place was not filled.

Vice-Presidents of Sections, Continued.

33. R. H. Thurston, 1884.
34. J. Burkitt Webb, 1885.
35. O. Chanute, 1886.
36. E. B. Coxe, 1887.
37. C. J. H. Woodbury, 1888.
38. James E. Denton, 1889.
39. James E. Denton, 1890, in place of A. Beardsley, absent.

Section D—Mechanical Science and Engineering, continued.

40. Thomas Gray, 1891.
41. J. B. Johnson, 1892.
42. S. W. Robinson, 1893.
43. Mansfield Merriman, 1894.
44. William Kent, 1895.
45. Frank O. Marvin, 1896.
46. John Galbraith, 1897.
47. John Galbraith, 1898, in the absence of M. E. Cooley.
48. Storm Bull, 1899.
49. John A. Brashear, 1900.
50. H. S. Jacoby, 1901.
51. J. J. Flather, 1902.
52. Clarence A. Waldo, 1903.

Section E.—Geology and Geography.

31. E. T. Cox, 1882.
32. C. H. Hitchcock, 1883.
33. N. H. Winchell, 1884.
34. Edward Orton,* 1885.
35. T. C. Chamberlin, 1886.
36. G. K. Gilbert, 1887.
37. George H. Cook,* 1888.
38. Charles A. White, 1889.
39. John C. Branner, 1890.
40. J. J. Stevenson, 1891.
41. H. S. Williams, 1892.
42. Charles D. Walcott, 1893.
43. Samuel Calvin, 1894.
44. Jed. Hotchkiss, 1895.
45. B. K. Emerson, 1896.
46. { I. C. White, 1897.
E. W. Claypole,* 1897. }
47. H. L. Fairchild, 1898.
48. J. F. Whiteaves, 1899.
49. J. F. Kemp, 1900.
50. C. R. Van Hise, 1901.
51. Joseph A. Holmes, 1902, in the absence of O. A Derby.
52. Wm. M. Davis, 1903.

Section F.—Biology, 1882–1892.

31. W. H. Dall, 1882.
32. W. J. Beal, 1883.
33. E. D. Cope,* 1884.
34. T. J. Burrill, 1885, in the absence of B. G. Wilder.
35. H. P. Bowditch, 1886.
36. W. G. Farlow, 1887.
37. C. V. Riley,* 1888.
38. George L. Goodale, 1889.
39. C. S. Minot, 1890.
40. J. M. Coulter, 1891.
41. S. H. Gage, 1892.

Section F.—Zoology.

42. Henry F. Osborn, 1893.
43. J. A. Lintner,* 1894, in place of S. H. Scudder, res'd.
44. L. O. Howard, 1895, in place of D. S. Jordan, res'd.
45. Theo. Gill, 1896.
46. L. O. Howard, 1897, in place of G. Brown Goode,* deceased.
47. A. S. Packard, 1898.
48. S. H. Gage, 1899.
49. C. B. Davenport, 1900.
50. D. S. Jordan, 1901.
51. E. L. Mark, 1902, in the absence of C. C. Nutting.
52. C. W. Hargitt, 1903.

Section G. Microscopy, 1882–85.

31. A. H. Tuttle, 1882.

VICE-PRESIDENTS OF SECTIONS, CONTINUED.

32. J. D. Cox, 1883.
33. T. G. Wormley,* 1884.
34. S. H. Gage, 1885.
(Section united with F in 1886)

Section G.—Botany.

42. Charles E. Bessey, 1893.
43. { L. M. Underwood, 1894. / C. E. Bessey, 1894. }
44. J. C. Arthur, 1895.
45. N. L. Britton, 1896.
46. G. F. Atkinson, 1897.
47. W. G. Farlow, 1898.
48. C. R. Barnes, 1899.
49. W. Trelease, 1900.
50. B. T. Galloway, 1901.
51. C. E. Bessey, 1902, in the absence of D. H. Campbell.
52. F. V. Coville, 1903.

Section H.—Anthropology.

31. Alex. Winchell,* 1882.
32. Otis T. Mason, 1883.
33. Edward S. Morse, 1884.
34. J. Owen Dorsey,* 1885, in the absence of W. H. Dall.
35. Horatio Hale,* 1886.
36. D. G. Brinton,* 1887.
37. Charles C. Abbott, 1888.
38. Garrick Mallery,* 1889.
39. Frank Baker, 1890.
40. Joseph Jastrow, 1891.
41. W. H. Holmes, 1892.
42. J. Owen Dorsey,* 1893.
43. Franz Boas, 1894.
44. F. H. Cushing,* 1895.
45. Alice C. Fletcher, 1896.
46. W J McGee, 1897.
47. J. McK. Cattell, 1898.
48. Thomas Wilson,* 1899.
49. A. W. Butler, 1900.
50. J. Walter Fewkes, 1901.
51. Stewart Culin, 1902.
52. Geo. A. Dorsey, 1903.

Section I.—Social and Economic Science.

31. E. B. Elliott,* 1882.
32. Franklin B. Hough,* 1883.
33. John Eaton,* 1884.
34. Edward Atkinson, 1885.
35. Joseph Cummings,* 1886.
36. H. E. Alvord, 1887.
37. Charles W. Smiley, 1888.
38. Charles S. Hill, 1889.
39. J. Richards Dodge, 1890.
40. Edmund J. James, 1891.
41. L. F. Ward, 1892, in place of S. D. Horton,* resigned.
42. William H. Brewer, 1893.
43. Henry Farquhar, 1894.
44. B. E. Fernow, 1895.
45. W. L. Lazenby, 1896.
46. R. T. Colburn, 1897.
47. Archibald Blue, 1898.
48. Marcus Benjamin, 1899.
49. Marcus Benjamin, 1900, in the absence of C. M. Woodward.
50. John Hyde, 1901.
51. John Hyde, 1902, in the absence of Carroll D. Wright.
52. H. T. Newcomb, 1903.

Section K.—Physiology and Experimental Medicine.

51. W. H. Welch, 1902.
52. W. H. Welch, 1903.

SECRETARIES.

General Secretaries, 1848–

1. WALTER R. JOHNSON,* 1848
2. E. N. HORSFORD,* 1849, in the absence of JEFFRIES WYMAN.*
3. L. R. GIBBS, 1850, in the absence of E. C. HERRICK.*
4. E. C. HERRICK,* 1850.
5. WM. B. ROGERS,* 1851, in the absence of E. C. HERRICK.
6. WM. B. ROGERS,* 1851.
7. S. ST. JOHN,* 1853, in the absence of J. D. DANA.*
8. J. LAWRENCE SMITH,* 1854.
9. WOLCOTT GIBBS, 1855.
10. B. A. GOULD,* 1856.
11. JOHN L. LECONTE,* 1857.
12. W.M.GILLESPIE,*1858,in the absence of WM.CHAUVENET,*
13. WM. CHAUVENET,* 1859.
14. JOSEPH LECONTE,* 1860.
15. ELIAS LOOMIS,* 1866, in the absence of W. P. TROWBRIDGE.*
16. C. S. LYMAN,* 1867.
17. SIMON NEWCOMB, 1868, in the absence of A.P.ROCKWELL.
18. O. C. MARSH,* 1869.
19. F. W. PUTNAM, 1870, in the absence of C. F. HARTT.*
20. F. W. PUTNAM, 1871.
21. EDWARD S. MORSE, 1872.
22. C. A. WHITE, 1873.
23. A. C. HAMLIN, 1874.
24. S. H. SCUDDER, 1875.
25. T. C. MENDENHALL, 1876.
26. AUG. R. GROTE, 1877.
27. H. C. BOLTON, 1878.
28. H. C. BOLTON, 1879, in the absence of GEORGE LITTLE.
29. J. K. REES, 1880.
30. C. V. RILEY,* 1881.
31. WILLIAM SAUNDERS, 1882.
32. J. R. EASTMAN, 1883.
33. ALFRED SPRINGER, 1884.
34. C. S. MINOT, 1885.
35. S. G. WILLIAMS,* 1886.
36. WILLIAM H. PETTEE, 1887.
37. JULIUS POHLMAN, 1888.
38. C. LEO MEES, 1889.
39. H. C. BOLTON, 1890.
40. H. W. WILEY, 1891.
41. A. W. BUTLER, 1892.
42. T. H. NORTON, 1893.
43. H. L. FAIRCHILD, 1894.
44. JAS. LEWIS HOWE, 1895.
45. CHARLES R. BARNES, 1896.
46. ASAPH HALL, JR., 1897.
47. J. MCMAHON, 1898, in place of D.S.KELLICOTT,*deceased.
48. F. BEDELL, 1899.
49. CHAS. BASKERVILLE, 1900.
50. JOHN M. COULTER, 1901, in the absence of WILLIAM HALLOCK.
51. D. T. MACDOUGAL, 1902.
52. HENRY B. WARD, 1903.

Permanent Secretaries, 1851–

5–7. SPENCER F. BAIRD,*1851–4

8–17. JOSEPH LOVERING,*1854–68.

18. F. W. PUTNAM, 1869, in the absence of J. LOVERING.*

19–21. JOSEPH LOVERING,* 1870–73.

22–46. F. W. PUTNAM, 1873–98.

47–53. L. O. HOWARD, 1898–05.

Assistant General Secretaries, 1882–1887.

31. J. R. EASTMAN, 1882.
32. ALFRED SPRINGER, 1883.
33. C. S. MINOT, 1884, in the absence of E. S. HOLDEN.
34. S. G. WILLIAMS,* 1885, in the absence of C. C. ABBOTT.

SECRETARIES, CONTINUED.

35. W. H. PETTEE, 1886.
36. J. C. ARTHUR, 1887.

Secretaries of the Council, 1888–

37. C. LEO MEES, 1888.
38. H. C. BOLTON, 1889.
39. H. W. WILEY, 1890.
40. A. W. BUTLER, 1891.
41. T. H. NORTON, 1892.
42. H. LEROY FAIRCHILD, 1893.
43. JAS. LEWIS HOWE, 1894.
44. CHARLES R. BARNES, 1895.
45. ASAPH HALL, JR., 1896.
46. D. S. KELLICOTT,* 1897.
47. FREDERICK BEDELL, 1898.
48. CHARLES BASKERVILLE, 1899.
49. WILLIAM HALLOCK, 1900.
50. D. T. MACDOUGAL, 1901.
51. H. B. WARD, 1902.
52. CH. WARDELL STILES, 1903.

Secretaries of Section A.—Mathematics, Physics and Chemistry, 1875–1881.

24. S. P. LANGLEY, 1875. T. C. MENDENHALL, 1875.
25. A. W. WRIGHT, 1876.
26. H. C. BOLTON, 1877.
27. F. E. NIPHER, 1878.
28. J. K. REES, 1879.
29. H. B. MASON, 1880.
30. E. T. TAPPAN, 1881, in the absence of JNO. TROWBRIDGE.

Secretaries of Section B.—Natural History, 1874–1881.

24. EDWARD S. MORSE, 1875.
25. ALBERT H. TUTTLE, 1876.
26. WILLIAM H. DALL, 1877.
27. GEORGE LITTLE, 1878.
28. WM. H. DALL, 1879, in the absence of A. C. WETHERBY.
29. CHARLES V. RILEY,* 1880.
30. WILLIAM SAUNDERS, 1881.

SECRETARIES OF SUBSECTIONS, 1875–1881.

Subsection of Chemistry.

24. F. W. CLARKE, 1875.
25. H. C. BOLTON, 1876.
26. P. SCHWEITZER, 1877.
27. A. P. S. STUART, 1878.
28. W. R. NICHOLS,* 1879.
29. C. E. MUNROE, 1880.
30. ALFRED SPRINGER, 1881, in the absence of R. B. WARDER.

Subsection of Entomology.

30. B. P. MANN, 1881.

Subsection of Anthropology.

24. F. W. PUTNAM, 1875.
25. OTIS T. MASON, 1876.

26, 27. United with Section B.

28, 29, 30. J. G. HENDERSON, 1879–81.

Subsection of Microscopy.

25. E. W. MORLEY, 1876.
26. T. O. SOMMERS, JR., 1877.
27. G. J. ENGELMANN, 1878.

28, 29. A. B. HERVEY, 1879–80.

30. W. H. SEAMAN, 1881, in the absence of S. P. SHARPLES.

SECRETARIES OF THE SECTIONS, 1882–

Section A.—Mathematics and Astronomy.

31. H. T. EDDY, 1882.
32. G. W. HOUGH, 1883, in the absence of W. W. JOHNSON.
33. G. W. HOUGH, 1884.
34. E. W. HYDE, 1885.
35. S. C. CHANDLER, 1886.
36. H. M. PAUL, 1887.
37. C. C. DOOLITTLE, 1888.

SECRETARIES OF THE SECTIONS, CONTINUED.

38. G. C. COMSTOCK, 1889.
39. W. W. BEMAN, 1890.
40. F. H. BIGELOW, 1891.
41. WINSLOW UPTON, 1892.
42. C. A. WALDO, 1893, in the absence of A. W. PHILLIPS.
43. J. C. KERSHNER, 1894, in place of W. W. BEMAN, res'd.
44. ASAPH HALL, JR., 1895, in place of E. H. MOORE, res'd.
45. EDWIN B. FROST, 1896.
46. JAMES MCMAHON, 1897.
47. WINSLOW UPTON, 1898, in place of ALEX. ZIWET, resigned.
48. JOHN F. HAYFORD, 1899.
49. W. M. STRONG, 1900.
50. G. A. MILLER, 1901, in place of H. C. LORD, resigned.
51. E. S. CRAWLEY, 1902.
52. C. S. HOWE, 1903.

Section B.—Physics.

31. C. S. HASTINGS, 1882.
32. F. E. NIPHER, 1883, in the absence of C. K. WEAD.
33. N. D. C. HODGES, 1884.
34. B. F. THOMAS, 1885, in place of A. A. MICHELSON, resigned.
35. H. S. CARHART, 1886.
36. C. LEO MEES, 1887.
37. ALEX. MACFARLANE, 1888.
38. E. L. NICHOLS, 1889.
39. E. M. AVERY, 1890.
40. ALEX. MACFARLANE, 1891.
41. BROWN AYRES, 1892.
42. W. LECONTE STEVENS, 1893.
43. B. W. SNOW, 1894.
44. E. MERRITT, 1895.
45. FRANK P. WHITMAN, 1896.
46. FREDERICK BEDELL, 1897.
47. W. S. FRANKLIN, 1898, in place of E. B. ROSA, resigned.
48. WILLIAM HALLOCK, 1899.
49. R. A. FESSENDEN, 1900.
50. JOHN ZELENY, 1901, in place of J. O. REED, resigned.
51. E. F. NICHOLS, 1902.
52. D. C. MILLER, 1903.

Section C.—Chemistry.

31. ALFRED SPRINGER, 1882.
32. { J. W. LANGLEY, 1883. W. MCMURTRIE, 1883.
33. H. CARMICHAEL, 1884, in the absence of R. B. WARDER.
34. F. P. DUNNINGTON, 1885.
35. W. MCMURTRIE, 1886.
36. C. F. MABERY, 1887.
37. W. L. DUDLEY, 1888.
38. EDWARD HART, 1889.
39. W. A. NOYES, 1890.
40. T. H. NORTON, 1891.
41. JAS. LEWIS HOWE, 1892.
42. H. N. STOKES, 1893, in the absence of J. U. NEF.
43. MORRIS LOEB, 1894, in place of S. M. BABCOCK, resigned.
44. { W. P. MASON, 1895. W. O. ATWATER, 1895.
45. FRANK P. VENABLE, 1896.
46. P. C. FREER, 1897.
47. C. BASKERVILLE, 1898.
48. H. A. WEBER, 1899.
49. A. A. NOYES, 1900.
50. W. MCPHERSON, 1901.
51. F. C. PHILLIPS, 1902.
52. H. N. STOKES, 1903.

Section D.—Mechanical Science and Engineering.

31. J. BURKITT WEBB, 1882, in the absence of C. B. DUDLEY.
32. J. BURKITT WEBB, 1883, *pro tempore.*
33. J. BURKITT WEBB, 1884.
34. C. J. H. WOODBURY, 1885.
35. WILLIAM KENT, 1886.
36. G. M. BOND, 1887.

Secretaries of the Sections, Continued.

37. Arthur Beardsley, 1888.
38. W. B. Warner, 1889.
39. Thomas Gray, 1890.
40. William Kent, 1891.
41. O. H. Landreth, 1892.
42. D. S. Jacobus, 1893.
43. John H. Kinealy, 1894.
44. H. S. Jacoby, 1895.
45. John Galbraith, 1896.
46. John J. Flather, 1897.
47. John J. Flather, 1898, in the absence of W. S. Aldrich.
48. J. M. Porter, 1899.
49. W. T. Magruder, 1900.
50. C. W. Comstock, 1901, in the absence of W. H. Jaques.
51. C. A. Waldo, 1902.
52. Albert Kingsbury, 1903.

Section E.—Geology and Geography.

31. H. S. Williams, 1882, in the absence of C. E. Dutton.
32. A. A. Julien, 1883.
33. E. A. Smith, 1884.
34. G. K. Gilbert, 1885, in the absence of H. C. Lewis.*
35. E. W. Claypole,* 1886.
36. W. M. Davis, 1887, in the absence of T. B. Comstock.
37. John C. Branner, 1888.
38. John C. Branner, 1889.
39. Samuel Calvin, 1890.
40. W J McGee, 1891.
41. R. D. Salisbury, 1892.
42. W. H. Hobbs,* 1893, in place of R. T. Hill, resigned.
43. Jed. Hotchkiss,* 1894, in place of W. M. Davis, res'd
44. J. Perrin Smith, 1895.
45. W. N. Rice, 1896, in place of A. C. Gill, resigned.
46. C. H. Smith, Jr., 1897.
47. Warren Upham, 1898.
48. Arthur Hollick, 1899.
49. J. A. Holmes, 1900.
50. H. B. Patton, 1901, in the absence of R. A. F. Penrose.
51. F. P. Gulliver, 1902.
52. E. O. Hovey, 1903.

Section F.—Biology, 1882–1892.

31. William Osler, 1882, in the absence of C. S. Minot.
32. S. A. Forbes, 1883.
33. C. E. Bessey, 1884.
34. J. A. Lintner,* 1885, in place of C. H. Fernald, res'd
35. J. C. Arthur, 1886.
36. J. H. Comstock, 1887.
37. B. E. Fernow, 1888.
38. A. W. Butler, 1889.
39. J. M. Coulter, 1890.
40. A. J. Cook, 1891.
41. D. B. Halstead, 1892.

Section F.—Zoology.

42. L. O. Howard, 1893.
43. John B. Smith, 1894, in place of Wm. Libby, Jr., resigned.
44. C. W. Hargitt, 1895, in place of S. A. Forbes, res'd.
45. D. S. Kellicott,* 1896.
46. C. C. Nutting, 1897.
47. R. T. Jackson, 1898, in place of C. W. Stiles, resigned.
48. C. L. Marlatt, 1899, in place of F. W. True, resigned.
49. C. H. Eigenmann, 1900.
50. H. B. Ward, 1901.
51. C. W. Stiles, 1902.
52. C. J. Herrick, 1903.

Section G.—Microscopy, 1882–85.

31. Robert Brown, Jr., 1882.
32. Carl Seiler, 1883.
33. Romyn Hitchcock, 1884.
34. W. H. Walmsley, 1885.

SECRETARIES OF THE SECTIONS, CONTINUED.

Section G.—Botany.

42. B. T. GALLOWAY, 1893, in the absence of F. V. COVILLE.
43. CHAS. R. BARNES, 1894.
44. { B. T. GALLOWAY, 1895. M. B. WAITE, 1895.
45. GEORGE F. ATKINSON, 1896.
46. F. C. NEWCOMBE, 1897.
47. ERWIN F. SMITH, 1898.
48. W. A. KELLERMAN, 1899.
49. D. T. MACDOUGAL, 1900.
50. ERNST A. BESSEY, 1901, in the absence of A. S. HITCHCOCK
51. H. VON SCHRENK, 1902.
52. C. J. CHAMBERLAIN, 1903.

Section H.—Anthropology.

31. OTIS T. MASON, 1882.
32. G. H. PERKINS, 1883.
33. G. H. PERKINS, 1884, in the absence of W. H. HOLMES.
34. ERMINNIE A. SMITH,* 1885.
35. A. W. BUTLER, 1886.
36. CHAS. C. ABBOTT, 1887, in the absence of F. W. LANGDON.
37. FRANK BAKER, 1888.
38. W. M. BEAUCHAMP, 1889.
39. JOSEPH JASTROW, 1890.
40. W. H. HOLMES, 1891.
41. W. M. BEAUCHAMP, 1892, in place of S. CULIN, resigned.
42. W. K. MOOREHEAD, 1893.
43. A. F. CHAMBERLIN, 1894.
44. { STEWART CULIN and W. W. TOOKER, 1895, in place of ANITA N. MCGEE, resigned.
45. G. H. PERKINS, 1896, in place of J. G. BOURKE,* dec'd.
46. ANITA N. MCGEE, 1897, in place of HARLAN I. SMITH, resigned.
47. MARSHALL H. SAVILLE, 1898.
48. E. W. SCRIPTURE, 1899, in place of GEO. A. DORSEY, resigned.
49. FRANK RUSSELL, 1900.
50. G. G. MACCURDY, 1901.
51. HARLAN I. SMITH, 1902.
52. R. B. DIXON, 1903.

Section I.—Social and Economic Science.

31. { FRANKLIN B. HOUGH,* 1882. J. RICHARDS DODGE, 1882.
32. JOSEPH CUMMINGS,* 1883.
33. CHARLES W. SMILEY, 1884.
34. CHAS. W. SMILEY, 1885, in the absence of J. W. CHICKERING.
35. H. E. ALVORD, 1886.
36. W. R. LAZENBY, 1887.
37. CHARLES S. HILL, 1888.
38. J. RICHARDS DODGE, 1889.
39. B. E. FERNOW, 1890.
40. B. E. FERNOW, 1891.
41. HENRY FARQUHAR, 1892, in place of L. F. WARD, made Vice-President.
42. NELLIE S. KEDZIE, 1893.
43. MANLEY MILES, 1894.
44. W. R. LAZENBY, 1895, in place of E. A. ROSS, resigned.
45. R. T. COLBURN, 1896.
46. ARCHIBALD BLUE, 1897.
47. MARCUS BENJAMIN, 1898.
48. CALVIN M. WOODWARD, 1899.
49. H. T. NEWCOMB, 1900.
50. R. A. PEARSON, 1901, in place of CORA A. BENNESON, resigned.
51. F. R. RUTTER, 1902, in place of Walter F. Willcox, resigned.
52. F. H. HITCHCOCK, 1903.

Section K.—Physiology and Experimental Medicine.

51. F. S. LEE, 1902.
52. F. S. LEE, 1903.

TREASURERS.

1. JEFFRIES WYMAN,* 1848.
2. A. L. ELWYN,* 1849.
3. ST. J. RAVENEL,* 1850, in the absence of A. L. ELWYN.*
4. A. L. ELWYN,* 1850.
5. SPENCER F. BAIRD,* 1851, in the absence of A. L. ELWYN,*
6–7. A. L. ELWYN,* 1851–53.
8. J. L. LECONTE,* 1854, in the absence of A. L. ELWYN.*
9–19. A. L. ELWYN,* 1855–1870.
20–30. WM. S. VAUX,* 1871–1881.
32–42. WM. LILLY,* 1882–93.
43–49. R. S. WOODWARD, 1894–1900.
50–54. R. S. WOODWARD, 1901–1904.

Commonwealth of Massachusetts.

In the Year One Thousand Eight Hundred and Seventy-Four.

AN ACT

TO INCORPORATE THE "AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE."

Be it enacted by the Senate and House of Representatives, in General Court assembled, and by the authority of the same, as follows:

SECTION 1. Joseph Henry of Washington, Benjamin Pierce of Cambridge, James D. Dana of New Haven, James Hall of Albany, Alexis Caswell of Providence, Stephen Alexander of Princeton, Isaac Lea of Philadelphia, F. A. P. Barnard of New York, John S. Newberry of Cleveland, B. A. Gould of Cambridge, T. Sterry Hunt of Boston, Asa Gray of Cambridge, J. Lawrence Smith of Louisville, Joseph Lovering of Cambridge, and John LeConte of Philadelphia, their associates, the officers and members of the Association, known as the "American Association for the Advancement of Science," and their successors, are hereby made a corporation by the name of the "American Association for the Advancement of Science," for the purpose of receiving, purchasing, holding, and conveying real and personal property, which it now is, or hereafter may be, possessed of, with all the powers and privileges, and subject to the restrictions, duties and liabilities set forth in the general laws which now or hereafter may be in force and applicable to such corporations.

SECTION 2. Said corporation may have and hold by purchase, grant, gift, or otherwise, real estate not exceeding one hundred thousand dollars in value, and personal estate of the value of two hundred and fifty thousand dollars.

SECTION 3. Any two of the corporators above named are hereby authorized to call the first meeting of the said corporation in the month of August next ensuing, by notice thereof "by mail," to each member of the said Association.

SECTION 4. This act shall take effect upon its passage.

HOUSE OF REPRESENTATIVES, March 10, 1874.
Passed to be enacted,
JOHN E. SANFORD, *Speaker*.

IN SENATE, March 17, 1874.
Passed to be enacted,
GEO. B. LORING, *President*.

March 19, 1874.
Approved.
W. B. WASHBURN.

SECRETARY'S DEPARTMENT,
Boston, April 3, 1874.
A true copy, Attest:
DAVID PULSIFER,
Deputy Secretary of the Commonwealth.

CONSTITUTION

OF THE

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Incorporated by Act of the General Court of the Commonwealth of Massachusetts.

OBJECTS.

ARTICLE 1. The objects of the Association are, by periodical and migratory meetings, to promote intercourse between those who are cultivating science in different parts of America, to give a stronger and more general impulse and more systematic direction to scientific research, and to procure for the labors of scientific men increased facilities and a wider usefulness.

MEMBERSHIP.

ART. 2. The Association shall consist of members, fellows, patrons, corresponding members and honorary fellows.

MEMBERS.

ART. 3. Any person may become a member of the Association upon recommendation in writing by two members or fellows, and election by the Council. Any incorporated scientific society or institution, or any public or incorporated library, may be enrolled as a member of the Association by vote of the Council by payment of the initiation fee; such society, institution, or library may be represented by either the President, Curator, Director, or Librarian presenting proper credentials at any meeting of the Association for which the assessment has been paid.

ASSOCIATES.

Associates for any single meeting shall be admitted on the payment of three dollars, such associates to have all the privileges of the meeting, except reading papers and voting.

Members of scientific societies whose meetings are contemporaneous with, or immediately subsequent to, that of the Associa-

tion, and which are recognized by vote of the Council as "Affiliated Societies," may become associate members for that meeting on the payment of three dollars. They shall be entitled to all the privileges of membership except voting or appointment to office, but their names shall not appear in the list of members printed in the annual report.

Foreign Associates.

Any member or fellow of any national scientific or educational institution, or of any society or academy of science, of any country not in America, who may be present at any meeting of the Association shall, on presenting the proper credentials, be enrolled without fee as a Foreign Associate, and shall be entitled to all the privileges of the meeting except voting on matters of business.

Fellows.

Art. 4. Fellows shall be elected by the Council from such of the members as are professionally engaged in science, or have, by their labors, aided in advancing science. The election of fellows shall be by ballot, and a majority vote of the members of the Council at a designated meeting of the Council.

Patrons.

Art. 5. Any person paying to the Association the sum of one thousand dollars shall be classed as a patron, and shall be entitled to all the privileges of a member and to all its publications.

Honorary Fellows and Corresponding Members.

Art. 6. Honorary fellows of the Association, not exceeding three for each Section, may be elected, the nominations to be made by the Council and approved by ballot in the respective sections before election by ballot in General Session. Honorary fellows shall be entitled to all the privileges of fellows, and shall be exempt from all fees and assessments, and entitled to all publications of the Association issued after the date of their election. Corresponding members shall consist of such scientists not residing in America as may be elected by the Council, and their number shall be limited to fifty. Corresponding members shall be entitled to

all the privileges of members and to the annual volumes of Proceedings published subsequent to their election.

SUSPENSIONS.

ART. 7. The name of any member or fellow two years in arrears for annual dues shall be erased from the list of the Association, provided, that two notices of indebtedness, at an interval of at least three months, shall have been given; and no such person shall be restored until he has paid his arrearages or has been re-elected. The Council shall have power to exclude from the Association any member or fellow, on satisfactory evidence that said member or fellow is an improper person to be connected with the Association, or has in the estimation of the Council made improper use of his membership or fellowship.

OFFICERS.

ART. 8. No member or fellow shall take part in the organization of, or hold office in, more than one section at any one meeting.

ART. 9. The officers of the Association shall be elected by ballot by the General Committee from the fellows, and shall consist of a President, a Vice-President from each section, a Permanent Secretary, a General Secretary, a Secretary of the Council, a Treasurer, and a Secretary of each Section; these, with the exception of the Permanent Secretary, the Treasurer, and the Secretaries of the Sections, shall be elected at each meeting for the following one, and, with the exception of the Treasurer and the Permanent Secretary, shall not be re-eligible for the next two meetings. The term of office of the Permanent Secretary, of the Treasurer, and of the Secretaries of the Sections, shall be five years.

PRESIDENT.

ART. 10. The President, or, in his absence, the senior Vice-President present, shall preside at all General Sessions of the Association and at all meetings of the Council. It shall also be the duty of the President to give an address at a General Session of the Association at the meeting following that over which he presided.

VICE-PRESIDENTS.

ART. 11. The Vice-Presidents shall be chairmen of their respective Sections, and of their Sectional Committees, and it

shall be part of their duty to give an address, each before his own Section, at such time as the Council shall determine at the meeting subsequent to that at which he presides. The Vice-Presidents may appoint temporary chairmen to preside over the sessions of their sections, but shall not delegate their other duties. The Vice-Presidents shall have seniority in order of their continuous membership in the Association.

General Secretary.

Art. 12. The General Secretary shall be the Secretary of all General Sessions of the Association, and shall keep a record of the business of these sessions. He shall receive the records from the Secretaries of the Sections, which, after examination, he shall transmit with his own records to the Permanent Secretary within two weeks after the adjournment of the meeting.

Secretary of the Council.

Art. 13. The Secretary of the Council shall keep the records of the Council. He shall give to the Secretary of each Section the titles of papers assigned to it by the Council. He shall receive proposals for membership and bring them before the Council.

Permanent Secretary.

Art. 14. The Permanent Secretary shall be the executive officer of the Association under the direction of the Council. He shall attend to all business not specially referred to committees nor otherwise constitutionally provided for. He shall keep an account of all business that he has transacted for the Association, and make annually a general report for publication in the annual volume of Proceedings. He shall attend to the printing and distribution of the annual volume of Proceedings, and all other printing ordered by the Association. He shall issue a circular of information to members and fellows at least three months before each meeting, and shall, in connection with the Local Committee, make all necessary arrangements for the meetings of the Association. He shall provide the Secretaries of the Association with such books and stationery as may be required for their records and business, and shall provide members and fellows with such blank forms as may be required for facilitating the business of the Association. He shall collect all assessments

and admission fees, and notify members and fellows of their election, and of any arrearages. He shall receive, and bring before the Council, the titles and abstracts of papers proposed to be read before the Association. He shall keep an account of all receipts and expenditures of the Association, and report the same annually at the first meeting of the Council, and shall pay over to the Treasurer such unexpended funds as the Council may direct. He shall receive and hold in trust for the Association all books, pamphlets, and manuscripts belonging to the Association, and allow the use of the same under the provisions of the Constitution and the orders of the Council. He shall receive all communications addressed to the Association during the intervals between meetings, and properly attend to the same. He shall at each meeting report the names of fellows and members who have died since the preceding meeting. He shall be allowed a salary which shall be determined by the Council, and may employ one or more clerks at such compensation as may be agreed upon by the Council.

Treasurer.

Art. 15. The Treasurer shall invest the funds received by him in such securities as may be directed by the Council. He shall annually present to the Council an account of the funds in his charge. No expenditure of the principal in the hands of the Treasurer shall be made without a unanimous vote of the Council, and no expenditure of the income received by the Treasurer shall be made without a two-thirds vote of the Council. The Treasurer shall give bonds for the faithful performance of his duty in such manner and sum as the Council shall from time to time direct.

Secretaries of the Sections.

Art. 16. The Secretaries of the Sections shall keep the records of their respective Sections, and, at the close of the meeting, give the same, including the records of subsections, to the General Secretary. They shall also be the Secretaries of the sectional committees. The Secretaries shall have seniority in order of their continuous membership in the Association.

Vacancies.

Art. 17. In case of a vacancy in the office of President, the senior Vice-President shall preside, as provided in Article 10,

until the General Committee can be assembled and the vacancy filled by election. Vacancies in the offices of Vice-President, Permanent Secretary, Secretary of the Council, Secretaries of the Sections, and Treasurer, shall be filled by the Council by ballot.

COUNCIL.

ART. 18. The Council shall consist of the Past Presidents, and the Vice-Presidents of the last two meetings, together with the President, the Vice-Presidents, the Permanent Secretary, the General Secretary, the Secretary of the Council, the Secretaries of the Sections, and the Treasurer of the current meeting, of one fellow elected from each Section by ballot on the first day of its meeting, of one fellow elected by each affiliated society, and one additional fellow from each affiliated society having more than twenty-five members who are fellows of the Association, and of nine fellows elected by the Council, three being annually elected for a term of three years. The members present at any regularly called meeting of the Council, provided there are at least five, shall form a quorum for the transaction of business. The Council shall meet on the day preceding each annual meeting of the Association, and arrange the program for the first day of the sessions. The time and place of this first meeting shall be designated by the Permanent Secretary. Unless otherwise agreed upon, regular meetings of the Council shall be held in the Council room at 9 o'clock A. M., on each day of the meeting of the Association. Special meetings of the Council may be called at any time by the President. The Council shall be the board of supervision of the Association, and no business shall be transacted by the Association that has not first been referred to, or originated with, the Council. The Council shall decide which papers, discussions, and other proceedings shall be published, and have the general direction of the publications of the Association; manage the financial affairs of the Association; arrange the business and programs for General Sessions; suggest subjects for discussion, investigation or reports; elect members and fellows; and receive and act upon all invitations extended to the Association and report the same at a General Session of the Association. The Council shall receive all reports of Special Committees and decide upon them, and only such shall be read in General

Session as the Council shall direct. The Council shall appoint at each meeting the following subcommittees who shall act, subject to appeal to the whole Council, until their successors are appointed at the following meeting: 1, on Papers and Reports; 2, on Members; 3, on Fellows.

General Committee.

ART. 19. The General Committee shall consist of the Council and one member or fellow elected by each of the Sections, who shall serve until their successors are elected. It shall be the duty of the committee to meet at the call of the President and elect the general officers for the following meeting of the Association. It shall also be the duty of this committee to fix the time and place for the next meeting. The Vice-President and Secretary of each Section shall be recommended to the General Committee by the Sectional Committee.

Meetings.

ART. 20. The Association shall hold a public meeting annually, for one week or longer, at such time and place as may be determined by vote of the General Committee, and the preliminary arrangements for each meeting shall be made by the Local Committee, in conjunction with the Permanent Secretary and such other persons as the Council may designate.

But if suitable preliminary arrangements cannot be made, the Council may afterward change the time and place appointed by the General Committee, if such change is believed advisable, by two-thirds of the members present.

ART. 21. A General Session shall be held at 10 o'clock, A. M., on the first day of the meeting, and at such other times as the Council may direct.

Sections and Subsections.

ART. 22. The Association shall be divided into Sections, namely:—A, *Mathematics and Astronomy;* B, *Physics;* C, *Chemistry, including its application to Agriculture and the Arts;* D, *Mechanical Science and Engineering;* E, *Geology and Geography;* F, *Zoology;* G, *Botany;* H, *Anthropology;* I, *Social and Economic Science;* K, *Physiology and Experimental Medicine.* The Council shall have

power to consolidate any two or more Sections temporarily, and such consolidated Sections shall be presided over by the senior Vice-President and Secretary of the Sections comprising it.

SECTIONAL COMMITTEES.

ART. 23. Immediately on the organization of a Section there shall be a member or fellow elected by ballot after open nomination, who, with the Vice-President and Secretary and the Vice-President and Secretary of the preceding meeting, and the members or fellows elected by ballot at the four preceding meetings, shall form its Sectional Committee. The Sectional Committees shall have power to fill vacancies in their own numbers. Meetings of the Sections shall not be held at the same time with a General Session. The Sectional Committee may invite distinguished foreign associates present at any meeting to serve as honorary members of said Committee.

ART. 24. The Sectional Committee of any Section may at its pleasure form one or more temporary Subsections, and may designate the officers thereof. The Secretary of a Subsection shall, at the close of the meeting, transmit his records to the Secretary of the Section.

ART. 25. No paper shall be read in any Section or Subsection until it has been placed on the program of the day by the Sectional Committee.

ART. 26. The Sectional Committees shall arrange and direct the business of their respective Sections. They shall prepare the daily programs and give them to the Permanent Secretary for printing at the earliest moment practicable. No titles of papers shall be entered on the daily programs except such as have passed the Committee. No change shall be made in the program for the day in a Section without the consent of the Sectional Committee. The Sectional Committees may refuse to place the title of any paper on the program; but every such title, with the abstract of the paper or the paper itself, must be referred to the Council with the reasons why it was refused. The Sectional Committee shall also make nominations to the General Committee for Vice-President and Secretary of their respective Sections as provided for in Article 19.

ART. 27. The Sectional Committees shall examine all papers and abstracts referred to the Sections, and they shall not place

on the program any paper inconsistent with the character of the Association; and to this end they have power to call for any paper, the character of which may not be sufficiently understood from the abstract submitted.

Papers and Communications.

Art. 28. All members and fellows must forward to the Secretary of the proper Section or to the Permanent Secretary, as early as possible. and when practicable before the convening of the Association, full titles of all the papers which they propose to present during the meeting, with a statement of the time that each will occupy in delivery, and also such abstracts of their contents as will give a general idea of their nature; and no title shall be considered by a Sectional Committee until an abstract of the paper or the paper itself has been received.

Art. 29. If the author of any paper be not ready when called upon, in the regular order of the official program, the title may be dropped to the bottom of the list.

Art. 30. Whenever practicable the proceedings and discussions at General Sessions, Sections and Subsections, shall be reported by professional reporters, but such reports shall not appear in print as the official reports of the Association unless revised by the Secretaries.

Printed Proceedings.

Art. 31. The Permanent Secretary shall have the Proceedings of each meeting printed in an octavo volume as soon after the meeting as possible, beginning one month after adjournment. Authors must prepare their papers or abstracts ready for the press, and these must be in the hands of the Secretaries of the Sections before the final adjournment of the meeting, otherwise only the titles will appear in the printed volume. The Council shall have power to order the printing of any paper by abstract or title only. Whenever practicable, proofs shall be forwarded to authors for revision. If any additions or substantial alterations are made by the author of a paper after its submission to the Secretary, the same shall be distinctly indicated. Illustrations must be provided for by the authors of the papers, or by a special appropriation from the Council. Immediately on publication of

the volume, a copy shall be forwarded to every member and fellow of the Association who shall have paid the assessment for the meeting to which it relates, and it shall also be offered for sale by the Permanent Secretary at such price as may be determined by the Council. The Council shall also designate the institutions to which copies shall be distributed.

Local Committee.

Art. 32. The Local Committee shall consist of persons interested in the objects of the Association and residing at or near the place of the proposed meeting. It is expected that the Local Committee, assisted by the officers of the Association, will make all essential arrangements for the meeting, and issue a circular giving necessary particulars, at least one month before the meeting.

Library of the Association.

Art. 33. All books and pamphlets received by the Association shall be in charge of the Permanent Secretary, who shall have a list of the same printed and shall furnish a copy to any member or fellow on application. Members and fellows who have paid their assessments in full shall be allowed to call for books and pamphlets, which shall be delivered to them at their expense on their giving a receipt agreeing to make good any loss or damage, and to return the same free of expense to the Secretary at the time specified in the receipt given. All books and pamphlets in circulation must be returned at each meeting. Not more than five books, including volumes, parts of volumes, and pamphlets, shall be held at one time by any member or fellow. Any book may be withheld from circulation by order of the Council. [The Library of the Association was, by vote of the Council in 1895, placed on deposit in the Library of the University of Cincinnati, Ohio. Members can obtain the use of books by writing to the Librarian of the University Library, Cincinnati, Ohio.]

Admission Fee and Assessments.

Art. 34. The admission fee for members shall be five dollars in addition to the annual assessment. On the election of any member as a fellow an additional fee of two dollars shall be paid.

ART. 35. The annual assessment for members and fellows shall be three dollars.

ART. 36. Any member or fellow who shall pay the sum of fifty dollars to the Association, at any one time, shall become a Life Member, and as such shall be exempt from all further assessments, and shall be entitled to the Proceedings of the Association. All money thus received shall be invested as a permanent fund, the income of which, during the life of the member, shall form a part of the general fund of the Association; but, after his death, shall be used only to assist in original research, unless otherwise directed by unanimous vote of the Council.

ART. 37. All fees and assessments must be paid to the Permanent Secretary, who shall give proper receipts for the same.

ACCOUNTS.

ART. 38. The accounts of the Permanent Secretary and of the Treasurer shall be audited annually by Auditors appointed by the Council.

ALTERATIONS OF THE CONSTITUTION.

ART. 39. No part of this Constitution shall be amended or annulled, without the concurrence of three-fourths of the members and fellows present in General Session, after notice given at a General Session of a preceding meeting of the Association.

MEMBERS AND FELLOWS

OF THE

AMERICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE.

(CORRECTED TO JULY 15, 1902.)

SURVIVING FOUNDERS.

[At the Brooklyn Meeting, 1894, a resolution was unanimously adopted by which all the surviving founders of the Association who have maintained an interest in science were made Honorary Life Members of the Association in recognition of their pioneer work in American Science.]

ABBOT, SAMUEL L., Boston, Mass.
BOYÉ, MARTIN H., Coopersburg, Pa.
GIBBS, WOLCOTT, Newport, R. I.

PATRONS.

[Persons contributing one thousand dollars or more to the Association are classed as Patrons, and are entitled to the privileges of members and to the publications. The names of Patrons are to remain permanently on the list.]

THOMPSON, MRS. ELIZABETH, Stamford, Conn. (22). (Died July 1899.)

LILLY, GEN. WILLIAM, Mauch Chunk, Pa. (28). (Died Dec. 1, 1893.)

HERRMAN, MRS. ESTHER, 59 West 56th St., New York, N. Y. (29).

McMILLIN, EMERSON, 40 Wall St., New York, N. Y. (37).

HONORARY FELLOWS.

[See ARTICLE VI of the Constitution.]

*ROGERS, PROF. WILLIAM B., Boston, Mass. (1). 1881. (Born Dec. 7, 1804. Died May 30, 1882.) **B E**

*CHEVREUL, MICHEL EUGENE, Paris, France. (35). 1886. (Born Aug. 31, 1786. Died April 9, 1889.) **C**

*GENTH, DR. F. A., Philadelphia, Pa. (24). 1888. (Born May 17, 1820. Died Feb. 2, 1892.) **C E**

*HALL, PROF. JAMES, Albany, N. Y. (1). 1890. (Born in 1811. Died Aug. 7, 1898.)

*GOULD, DR. BENJAMIN APTHORP, Cambridge, Mass. (2). 1895. (Born Sept. 27, 1824. Died Nov. 26. 1896.) **A B**

*LEUCKART, PROF. RUDOLF. (44). 1895. (Born in Helmstedt. Braunschweig, Germany, Oct. 7, 1823. Died in Leipzig, Feb. 7, 1898.) **F**

*GIBBS, PROF. WOLCOTT, Newport, R. I. (1). 1896. **B C**

*WARINGTON, ROBERT, F. R. S., Rothamsted, Harpenden, England. (40). 1899. **C**

*WESTINGHOUSE, GEORGE, Pittsburg, Pa. (50). 1902. **D**

MEMBERS AND FELLOWS.

The names designated by an asterisk (*) are those of Fellows. (See ARTICLE IV of the Constitution.) The number in parenthesis indicates the meeting at which the Member joined the Association; the date following is the year when made a Fellow; the black letters at end of line are those of the Sections to which the Member or Fellow belongs. When the name is given in small capitals, it designates that the Member or Fellow is also a Life Member. Any Member or Fellow may become a Life Member by the payment of fifty dollars. The income of the money derived from a life membership is used for the general purposes of the Association during the life of the Member; afterwards it is to be used to aid in original research. Life Members are exempt from the annual assessment, and are entitled to the publications. The names of Life Members are printed in small capitals in the regular list of Members and Fellows.

The Constitution requires that the names of all Members two years in arrears shall be omitted from the list, but their names will be restored on payment of arrearages. Members not in arrears are entitled to the publications of the Association, including the journal *Science*.

*Abbe, Cleveland, Professor of Meteorology, Weather Bureau, U. S. Dept. Agriculture, Washington, D. C. (16). 1874. **A B**

*Abbe, Cleveland, Jr., 2017 I St., N. W., Washington, D. C. (44). 1899. **E**

*Abbe, Dr. Robert, 13 W. 50th St., New York, N. Y. (36). 1892.

*Abbot, Charles G., Smithsonian Institution, Washington, D. C. (49). 1902 **B**

Abbot, Francis Ellingwood, Ph.D., 43 Larch Road, Cambridge, Mass. (50). **I**

*ABBOT, DR. SAMUEL L., 90 Mt. Vernon St., Boston, Mass. (1). 1898.

Abbott, Frank L., Professor of Physical Science, State Normal School, Greeley, Colo. (50). **B E**

Abel, John J., Professor of Pharmacology, Johns Hopkins University, Baltimore, Md. (51). **C**

*Abert, S. Thayer, Metropolitan Club, Washington, D. C. (30). 1891. **A B E**

Abraham, Abraham, Brooklyn, N. Y. (43).

Acheson, Edward Goodrich, President of the International Acheson Graphite Co., Niagara Falls, N. Y. (50). **C**

Adams, Comfort A., 13 Farrar St., Cambridge, Mass. (47).

Adams, C. C., University of Chicago, Chicago, Ill. (50). **F**

Adams, C. E., M. D., 29 West Broadway, Bangor, Me. (43). **F**
Adams, Edward Dean, 35 Wall St., New York, N. Y. (49).
Adams, Ernest Kempton, 455 Madison Ave., New York, N. Y. (50). **D E**
Adams, Frederick C., Classical High School, Providence, R. I. (50). **B C**
Adler, I., M. D., 12 E 60th St., New York, N. Y. (49).
*Adriance, John S., 105 E. 39th St., New York, N. Y. (39). 1895. **C**
Ainsworth, Herman Reeve, M. D., Addison, N. Y. (51). **I K**
Albaugh, Maurice, Secretary of the Crescent Metallic Fence Stay Co., Covington, Ohio. (51). **D**
Albrecht, Emil Poole, Secretary of The Bourse, 1523 No. 17th St., Philadelphia, Pa. (51). **A D**
Albree, Chester B., Mechanical Engineer, 14–30 Market St., Allegheny, Pa. (50). **D**
*Alden, John, Pacific Mills, Lawrence, Mass. (36). 1898.
Alderson, Victor C., Dean of the Technical College, Armour Institute of Technology, Chicago, Ill. (50). **D**
Aldis, Owen F., 230 Monadnock Block, Chicago, Ill. (41). **H**
*Aldrich, Wm. S., Director, Thomas S. Clarkson Memorial School of Technology, Potsdam, N. Y. (43). 1897. **D**
Alexander, Chas. Anderson, M. E., Johnston Harvester Co., 10 Vine St., Batavia, N. Y. (50). **D**
Alexander, Curtis, Mining Engineer, Spearfish, South Dakota. (50). **E**
Alexander, George E., Chemist and Mining Engineer, 1736 Champa St., Denver, Colo. (50). **C D**
Alexander, Harry, E. E., M. E., 18 and 20 W. 34th St., New York, N. Y. (50). **D**
Aley, Robert J., Indiana Univ., Bloomington, Ind. (49).
Alford, William V., Garrettsville, Ohio. (48). **E H**
Allan, Chas. F., Newburgh, N. Y. (50). **B E**
Allderdice, Wm. H., Lieutenant U. S. Navy, Navy Dept. Washington, D. C. (33). **D**
Alleman, Gellert, Ph. D., Instructor in Chemistry, Washington University, St. Louis, Mo. (50). **C**
Allen, C. L., Floral Park, N. Y. (49).
Allen, Frank, 315 Dryden Road, Ithaca, N. Y. (49). **B**
Allen, H. Jerome, M. D., 421 H St., N.E., Washington, D. C. (51). **K**
Allen, J. M., President of the Hartford Steam Boiler Inspection and Insurance Co., Hartford, Conn. (22). **D**
Allen, John Robins, Asst. Prof. of Mechanical Engineering, University of Michigan, Ann Arbor, Mich. (45). **B D**
Allen, Richard H., Chatham, N. J. (49).
*Allen, Dr. T. F., 3 E. 48th St., New York, N. Y. (35). 1887. **G**

Allen, Walter S., 34 S. Sixth St., New Bedford, Mass. (39). **C I**
Allison, Charles Edward, M. D., Elysburg, Pa. (51). **K**
Allison, Hendery, M. D., Manhattan State Hospital, East, P. O. Sta. U, New York, N. Y. (50). **K**
Allyn, G. W., M. D., Secretary Academy of Science and Art, 515 Penn. Ave., Pittsburg, Pa. (51). **F**
Almond, Thomas R., M. E., 83–85 Washington St., Brooklyn, N. Y. (51). **D**
*Almy, John E., Ph. D., Instructor in Physics, University of Nebraska, Lincoln, Neb. (50). 1901. **B**
Alpers, Wm. C., 45 West 31st St., New York, N. Y. (50). **I**
Alsop, E. B., 541 Wood St., Pittsburg, Pa. (50). **D**
Alspach, E. F., 455 West Sixth Ave., Columbus, O. (48). **H**
*Alvord, Maj. Henry E., U. S. Dept. Agriculture, Washington, D. C. (29). 1882. **I**
*Alwood, Prof. Wm. B., Agricultural and Mechanical College and Experiment Station, Blacksburg, Va. (39). 1891. **F**
Ames, Oakes, Assistant Director of the Botanic Garden of Harvard University, North Easton, Mass. (50). **G**
Ammons, Miss Theodosia G., Professor of Domestic Science, State Agricultural College, Fort Collins, Colo. (50). **I**
Amundson, John A., 146 Broadway, New York, N. Y. (49).
Amweg, Frederick James, Civil and Consulting Engineer, Box 537, Honolulu, H. T. (51). **D**
Anders, Howard S., M. D., 1836 Wallace St., Philadelphia, Pa. (51). **K**
Anderson, A. J. C., 127 Water St., New York, N. Y. (49).
*Anderson, Alexander P., N. Y. Botanical Garden, Bronx Park, New York, N. Y. (45). 1899. **G**
Anderson, Prof. Douglas S., Tulane Univ., New Orleans, La. (49). **B D**
Anderson, Edwin Clinton, M. D.,7 26 Market St., Chattanooga, Tenn. (51). **K**
Anderson, Frank, E. M., 255 Second East St., Salt Lake City, Utah, (50). **D E**
Anderson, Frank P., Epworth, Iowa. (46).
Anderson, J. Hartley, M. D., 4630 Fifth Ave., Pittsburg, Pa. (50). **K**
Anderson, James Thomas, Lieutenant U. S. Army, 1112 N. Cascade Ave., Colorado Springs, Colo. (51).
Anderson, Winslow, M. D., President of College of Physicians and Surgeons of San Francisco, 1025 Sutter St., San Francisco, Cal. (51). **K**
Andrews, Wm. C., Associate Editor, "Street Railway Journal," Hotel Margaret, New York, N. Y. (46).

Andrews, William Symes, care Gen'l Elec. Co., Schenectady, N. Y. (50). **D E**

Annear, John Brothers, University of Colorado, Boulder, Colo. (50). **C**

Anthony, Mrs. Emilia C., Gouverneur, N. Y. (47). **G**

Anthony, Richard A., 122–124 Fifth Ave., New York, N. Y. (49).

*Anthony, Prof. Wm. A., Cooper Union, New York, N. Y. (28). 1880. **B**

*Appleton, John Howard, Professor of Chemistry, Brown University, Providence, R. I. (50). 1901. **C**

Archer, George Frost, 31 Burling Slip, New York, N. Y. (50). **D**

Armstrong, Robert ,M. D., Boulder, Colo. (50). **H K**

Arnold, Bion Joseph, 4128 Prairie Ave., Chicago, Ill. (50). **D**

Arnold, Mrs. Francis B., 101 W. 78th St., New York, N. Y. (49).

Arnold, Jacob H., Teacher of Natural Science, Redfield College, Redfield, South Dakota. (50). **I**

Arnold, Ralph, Instructor in Mineralogy, Stanford University, Palo Alto, Cal. (51). **E**

*Arthur, J. C., Lafayette, Ind. (21). 1883. **G**

Asdale, William James, M. D., 5523 Ellsworth Ave., Pittsburg, Pa. (51). **K**

Ashbrook, Donald Sinclair, 3614 Baring St., Philadelphia, Pa. (51). **C**

Ashe, W. Willard, Consulting Forester, Raleigh, N. C. (47).

Ashley, George Hall, Professor of Biology and Geology, College of Charleston, Charleston, S. C. (51). **E F**

*Ashmead, Wm. H., Department of Insects, U. S. National Museum, Washington, D. C. (40). 1892. **F**

Aspinwall, John, 290 Broadway, New York, N. Y. (49).

Atkins, Prof. Martin D., Agricultural College, Mich. (48). **B**

*Atkinson, Edward, 31 Milk St., Boston, Mass. (29). 1881. **D I**

*Atkinson, George F., Cornell University, Ithaca, N. Y. (39). 1892. **G**

Atkinson, John B., Earlington, Ky. (26). **D**

*Atwater, Prof. W. O., Wesleyan Univ., Middletown, Conn. (29). 1882. **C**

*Auchincloss, Wm. S., 45 W. 20th St., New York, N. Y. (29). 1886. **A D**

*Austen, Prof. Peter T., 80 Broad St., New York, N. Y. (44). 1896. **C**

Austin, Dr. George M., Wilmington, Ohio. (48). **E F**

*Avery, Elroy M., Ph. D., LL.D., 657 Woodland Hills Ave., Cleveland, Ohio. (37). 1889. **B**

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Ayer, James I., 5 Main St. Park, Malden, Mass. (50). **D**

*Ayers, Howard, President Univ. of Cincinnati, Cincinnati, Ohio. (49). 1901. F

Aylesworth, Barton O., President of the State Agricultural College. Fort Collins, Colo. (50). I

*Ayres, Prof. Brown, Tulane University, New Orleans, La. (31). 1885. B

Ayres, Horace B., U. S. Geological Survey, Washington, D. C. (40).

Babcock, Stephen E., Civil and Hydraulic Engineer, Little Falls, N. Y. (51). D

*Babcock, Prof. S. Moulton, 432 Lake St., Madison, Wis. (33). 1885. C

Baerecke, John F., M. D., Professor of Biology, Stetson University, DeLand, Fla. (50). F K

Bagby, J. H. C., Dept. Physical Science, Hampden-Sidney College, Hampden-Sidney, Va. (50). B

Bagg, Rufus Mather, Jr., Ph. D., High School, Brockton, Mass. (49). E

BAGGALEY, RALPH, Pittsburg, Pa. (50). D

*Bailey, E. H. S., Professor of Chemistry, Univ. of Kansas, Lawrence, Kan. (25). 1889. C E

Bailey, Marshall Henry, M. D., 47 Brattle St., Cambridge, Mass. (50). F K

*Bailey, Solon Irving, Associate Prof. Astronomy, Harvard Observatory, Cambridge, Mass. (50). 1901. A

Bain, Samuel M., Professor of Botany, University of Tennessee, Knoxville, Tenn. (50). G

Baker, A. G., Springfield, Mass. (44).

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Baker, Hugh P., Bureau of Forestry, U. S. Dept. Agriculture, Washington, D. C. (51). G

Baker, James H., President of the University of Colorado, Boulder, Colo. (50). I

*Baker, Marcus, U. S. Geol. Survey, Washington, D. C. (30). 1882. A

Balch, Edwin Swift, 1412 Spruce St., Philadelphia, Pa. (51). E H

Balch, Francis Noyes, Prince St., Jamaica Plain, Mass. (50). F

Balch, Samuel W., 41 Wall St., New York, N. Y. (43).

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Baldwin, Herbert B., 9-11 Franklin St., Newark, N. J. (43).

*Baldwin, Prof. J. Mark, Princeton, N. J. (46). 1898. H

*BALDWIN, HON. SIMEON E., Associate Judge of Supreme Court of Errors, New Haven, Conn. (50). 1901. I

*BALDWIN, S. PRENTISS, 736 Prospect St., Cleveland, Ohio. (47). 1900. E

*Ball, Carleton R., U. S. Dept. Agriculture, Washington, D. C. (49). 1902. G

Ball, Elmer Darwin, Assistant Professor of Zoology, Agricultural College, Fort Collins, Colo. (50). F

Ball, Miss Helen Augusta, 43 Laurel St., Worcester, Mass. (50). F

Ballard, C. A., Curator of Museum, State Normal School, Moorhead, Minn. (51).

*Ballard, Harlan H., 50 South St., Pittsfield, Mass. (31). 1891. E F

Balliet, Thomas M., Supt. of Schools, Springfield, Mass. (48). H I

Bancroft, Alonzo C., Elma, New York. (41).

Bancroft, Frank Watts, Ph. D., Instructor in Physiology, University of California, Berkeley, Cal. (50). F K

Bancroft, John Sellers, M. E., 3310 Arch St., Philadelphia, Pa. (51). D

*Bancroft, Wilder Dwight, Professor of Chemistry, Cornell University, Ithaca, N. Y. (50). 1901. C

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Banks, William C., Electrician, Gordon Battery Co., 439 E. 144th St., New York, N. Y. (50). D

Barber, Amzi L., 7 E. 42d St., New York, N. Y. (49).

*Barbour, Prof. Erwin Hinckley, Univ. of Nebraska, Lincoln, Neb. (45). 1898. E

*Bardeen, Charles Russell, Anatomical Laboratory, Wolfe and Monument Sts., Baltimore, Md. (50). 1901. F K

BARGE, B. F., Mauch Chunk, Pa. (33).

Barkan, Adolph, M. D., LL.D., 14 Grant Ave., San Francisco, Cal. (51). K

*BARKER, PROF. G. F., 3909 Locust St., Philadelphia, Pa. (13). 1875. B C

Barker, Mrs. Martha M., 42 Eleventh St., Lowell, Mass. (31). E H

*Barnard, Edward E., Yerkes Observatory, Williams Bay, Wis. (26). 1883. A

Barnes, Albert, Clemson College, S. C. (49). D

*Barnes, Charles Reid, Ph. D., Univ. of Chicago, Chicago, Ill. (33). 1885. G

Barnes, Edward W., Box 446, New York, N. Y. (49).

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Barnett, Robert Crary, care Vera Cruz and Pacific Ry., Orizaba, Mexico. (51). D

Barnhart, Arthur M., 185 Monroe St., Chicago, Ill. (42).

Barnhart, John H., M. D., Tarrytown, N. Y. (49). G

Barnsley, George Thomas, C. E., 64 Water St., Pittsburg, Pa. (51). **D**

*Barnum, Miss Charlotte C., Ph. D., U. S. Coast and Geodetic Survey, Washington, D. C. (36). 1896. **A**

Barr, Charles Elisha, Professor of Biology, Albion College, Albion, Mich. (50). **F**

Barr, John Henry, Professor of Machine Design, Cornell University, Ithaca, N. Y. (51). **D**

Barrell, Joseph, Asst. Professor of Geology, Lehigh University, South Bethlehem, Pa. (51). **E**

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Barringer, Daniel Moreau, Geologist and Mining Engineer, 460 Bullitt Building, Philadelphia, Pa. (50). **D E**

Barrows, Franklin W., M. D., 45 Park St., Buffalo, N. Y. (47). **F**

*Barrows, Walter B., Agricultural College, Mich. (40). 1897. **F**

*Bartlett, Prof. Edwin J., Dartmouth College, Hanover, N. H. (28). 1883. **C**

Bartlett, Francis, 40 State St., Boston, Mass. (50). **I**

*Bartlett, John R., Captain, U. S. N., 1622 21st St., N.W., Washington, D. C. (30). 1882. **B E**

*Bartley, Elias H., M. D., 21 Lafayette Ave., Brooklyn, N. Y. (33). 1894. **C**

*Barton, G. E., 212 North 3d St., Millville, N. J. (46). 1898. **C**

*Barton, George Hunt, Dept. of Geology, Mass. Inst. Tech., Boston, Mass. (47). 1900. **E**

Barton, Philip Price, E. E., Sup't Niagara Falls Power Co., 127 Buffalo Ave., Niagara Falls, N. Y. (50). **D E**

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Bartow, Edward, Ph. D., Kansas State University, Lawrence, Kan. (47). **C**

*Barus, Carl, Ph. D., Wilson Hall, Brown Univ., Providence, R. I. (33). 1887. **B**

Barwell, John William, Waukegan, Ill. (47).

*Bascom, Miss Florence, Bryn Mawr College, Bryn Mawr, Pa. (42). 1897. **E**

Bashore, Dr. Harvey B., West Fairview, Pa. (46). **E**

*Baskerville, Charles, Univ. of North Carolina, Chapel Hill, N. C. (41). 1894. **C E**

Baskett, James Newton, Mexico, Mo. (50). **F I**

Bassett, Carroll Phillips, C. E., Ph. D., Civil and Consulting Engineer, Summit, N. J. (51). **D**

Bates, Charles B., M. D., 27 Everett St., Cambridge, Mass. (51). **C K**

Bates, Rev. John Mallery, Callaway, Neb. (51). **G I**

Bauder, Arthur Russell, Instructor in Physics, Boardman High School, New Haven, Conn. (50). B

*Bauer, Louis A., Ph. D., U. S. C. and G. Survey, Washington, D. C. (40). 1892. A

*Bausch, Edw., P. O. Drawer 1033, Rochester, N. Y. (26). 1883. A B C F

Bausch, Henry, P. O. Drawer 1033, Rochester, N. Y. (41).

Baxter, James Phinney, President, Maine Historical Society, Portland, Maine. (50). H I

Beach, Miss Alice M., 1015 W. Illinois St., Urbana, Ill. (50). F

Beach, Charles Coffing, M. D., 54 Woodland St., Hartford, Conn. (50). K

Beach, Harry Wilber, Manufacturer of Wood-working Machinery, Montrose, Pa. (50). D

Beach, Henry Harris Aubrey, M. D., 28 Commonwealth Ave., Boston, Mass. (50). F K

*Beach, Spencer Ambrose, N. Y. Exper. Station, Geneva, N. Y. (41). 1900. G

Beahan, Willard, Division Engineer, C. & N. W. Ry., 220 W. 6th St., Winona, Minn. (51). D

*Beal, Wm. James, Ph. D., Professor of Botany, Agricultural College, Mich. (17). 1880. G

*Beardsley, Arthur E., Professor of Biology, Colorado State Normal School, Greeley, Colo. (50). 1901. F

Beates, Henry, Jr., M. D., President of State Board of Medical Examiners, 1504 Walnut St., Philadelphia, Pa. (51). K

Beatty, James W. F., Pitcairn, Pa. (51).

Becher, Franklin A., 234 Oneida St., Milwaukee ,Wis. (41). A I

Beck, Carl, M. D., Visiting Surgeon, St. Mark's Hospital, 37 E. 31st St., New York, N. Y. (51). K

*Becker, Dr. Geo. F., U. S. Geol. Survey, Washington, D. C. (36). 1890. E

Beckwith, Miss Florence, 394 Alexander St., Rochester, N. Y. (45). G

*Bedell, Frederick, Ph. D., Cornell Univ., Ithaca, N. Y. (41). 1894. A B

Beede, Joshua William, Indiana University, Bloomington, Ind. (50). E

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Behrend, Bernhard Arthur, C. E., E. E., Station H. Cincinnati, Ohio. (50). D E

*Bell, Alex. Graham, 1331 Conn. Ave., N.W., Washington, D. C. (26). 1879. B H I

*Bell, Alex. Melville, 1525 35th St., Washington, D. C. (31). 1885. H

BELL, C. M., M. D., 320 Fifth Ave., New York, N. Y. (36).
Bell, George, Mineralogist, 200 S. Washington Ave., Denver, Colo. (50). **E G**
Bell, Guido, M. D., 431 E. Ohio St., Indianapolis, Ind. (51). **K**
*Bell, Robert, M. D., LL.D., F. R. S., Geol. Survey, Ottawa, Can. (38). 1889. **E F**
Bellows, Horace M., M. D., Huntingdon Valley, Pa. (51). **K**
Belmont, August, 23 Nassau St., New York, N. Y. (50). **I**
*Beman, Wooster W., 813 E. Kingsley St., Ann Arbor, Mich. (34). 1886. **A**
Benedict, James H., 14 E. 70th St., New York, N. Y. (49).
*BENJAMIN, MARCUS, U. S. National Museum, Washington, D. C. (27). 1887. **C I**
*Benjamin, Rev. Raphael, Hotel Premier, E. 72nd St., New York, N. Y. (34). 1887. **E F G H**
*Benneson, Miss Cora Agnes, A. M., LL. B., 4 Mason St., Cambridge, Mass. (47). 1899. **H I**
Bennett, Charles W., Coldwater, Mich. (50). **E**
Bennett, Henry C., 4th Flat, 1692 Broadway, New York, N. Y. (43).
Bennett, Rev. N. E., Wilmington, Ohio. (47). **A**
Bennett, William Z., Ph. D., Director of Chemical Laboratory, Univ. of Wooster, Wooster, Ohio. (48). **C**
Benson, Frank Sherman, 214 Columbia Heights, Brooklyn, N. Y. (49).
Bentley, William B., Ohio University, Athens, Ohio. (51). **C**
Bentley, Wilson A., Nashville, Vt. (48).
Bentley, Wray Annin, Instructor in Metallurgy, School of Applied Science, Columbia University, New York, N. Y. (50). **E**
Benton, John Robert, Ph. D., Asst. in Physics, Cornell University, Ithaca, N. Y. (51). **B**
Benton, Josiah H., Jr., Ames Building, Boston, Mass. (50). **I**
Bergey, David H., S. E. cor. 34th and Locust Sts. Philadelphia, Pa. (48).
*Bergström, John Andrew, Ph. D., Associate Professor of Psychology and Pedagogy, Indiana University, Bloomington, Ind. (50). 1901. **I**
Berkeley, Wm. N., Ph. D., Box 65, San Juan, Porto Rico. (49). **C**
Berkey, Charles Peter, Ph. D., Instructor in Mineralogy, University of Minnesota, Minneapolis, Minn. (50). **E**
Bermann, I., M. D., 1010 I St., N.W., Washington, D. C. (49). **H**
Bernays, Augustus Charles, M. D., 3623 Laclede Ave., St. Louis, Mo., (50). **F K**
Bernheimer, Charles L., 43 E. 63rd St., New York, N. Y. (49).
Berry, Daniel, M. D., Carmi, Ill. (41). **B C E**

Berry, Edgar H., Draftsman in charge Equipment Department, Navy Yard, Brooklyn, N. Y. (50). **D**

Berry, Edward W., News Building, Passaic, N. J. (50). **I**

Berry, John Wilson, C. E., Pittston, Pa. (47).

*Bessey, Charles Edwin, Ph. D., LL.D., Univ. of Nebraska, Lincoln, Neb. (21). 1880. **G**

*Bessey, Ernst A., U. S. Dep't Agriculture, Washington, D. C. (49). 1901. **G**

Bessey, J. Mortimer, M. D., 1814 Adams St., Toledo, Ohio. (51). **K**

Bethea, Solomon Hix, U. S. Attorney, Chicago Club, Chicago, Ill. (50). **I**

Bevier, Miss Isabel, Univ. of Illinois, Urbana, Ill. (46). **C**

*Beyer, Prof. Samuel W., Iowa Agricultural College, Ames, Iowa. (47). 1900. **E**

*Bickmore, Prof. Albert S., Amer. Mus. Nat. History, Central Park, New York, N. Y. (17). 1880. **H**

Biddle, James G., 1021 Stephen Girard Building, Philadelphia, Pa. (33).

Bien, Julius, 140 Sixth Ave., New York, N. Y. (34). **E H**

Bierly, Prof. H. E., State Seminary, Tallahassee, Fla. (49). **H**

Bierwirth, Juilus C., M. D., 137 Montague St., Brooklyn, N. Y. (51). **K**

*Bigelow, Prof. Frank H., U. S. Weather Bureau, Washington, D. C. (36). 1888. **A**

Bigelow, Maurice Alpheus, Ph. D., Instructor in Biology, Teachers' College, Columbia Univ., New York, N. Y. (51). **F**

Bigelow, Samuel Lawrence, Ph. D., Asst. Professor of General Chemistry, University of Michigan, Ann Arbor, Mich. (51). **C**

Biggar, Hamilton F., M. D., 176 Euclid Ave., Cleveland, Ohio. (40). **B F**

Biggs, Charles, 13 Astor Place, New York, N. Y. (50). **I**

Bigney, Andrew J., Professor of Biology and Geology, Moores Hill College, Moores Hill Ind. (50). **E F**

Billings, Miss E., 279 Madison Ave., New York, N. Y. (50). **I**

BISHOP, HEBER R., Mills Building, New York, N. Y. (36).

Bishop, L. B., M. D., 356 Orange St., New Haven, Conn. (50). **I**

Bissell, Leslie Dayton, Ph. D., Hotchkiss School, Lakeville, Conn. (50). **B**

*BIXBY, MAJOR W. H., Corps of Engineers, U. S. A., U. S. Engineer Office, Jones Bldg., Detroit, Mich. (34). 1892. **D**

Black, Newton Henry, 10 Westerly St., Roxbury, Mass. (50). **B**

Blackall, Clarence Howard, Architect, 1 Somerset St., Boston, Mass. (50). **D**

Blackburn, Joseph E., State Dairy and Food Commissioner, Columbus, Ohio, (50). **F I**

Blackmar, Frank Wilson, Professor of Sociology and Economics, University of Kansas, Lawrence, Kan. (50). H I

Blackmore, Henry S., 206 S. 9th Ave., Mount Vernon, N. Y. (49).

*Blair, Andrew Alexander, 406 Locust St., Philadelphia, Pa. (44). 1896. C

*Blake, Clarence J., M. D., 226 Marlborough St., Boston, Mass. (24). 1877. B F

*Blake, Edwin Mortimer, 1910 Addison St., Berkeley, Cal. (43). 1901. A

*Blake, Francis, Auburndale, Mass. (23). 1874. A B

Blake, Fred. C., Boulder, Colo. (50). C

Blake, John Bapst, M. D., 302 Beacon St., Boston, Mass. (50). F K

Blake, Joseph A., M. D., 601 Madison Ave., New York, N. Y. (50). K

Blakeman, Mrs. Birdseye, 9 E. 44th St., New York, N. Y. (49).

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Blakeslee, Olin Safford, Magnolia, Colo. (50). B D E

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Blankinship, Joseph William, Ph. D., Professor of Botany, Montana State College, Bozeman, Montana. (51). G

Blasdale, Walter Charles, Ph. D., Instructor in Chemistry, University of California, Berkeley, Cal. (50). C

Blauvelt, Harrington, Mining Engineer, Prescott, Arizona, (51). D E

*Bleile, Albert M., M. D., State University, Columbus, Ohio. (37). 1896. F

BLISH, W. G., Niles, Mich. (33). B D

Bliss, Charles B., Ph. D., The Elmer Gates Laboratory of Psychology and Psychurgy, Chevy Chase, Md. (49). H I

Bliss, Hon. Cornelius N., 117 Duane St., New York, N. Y. (49).

Bloodgood, John H., 6 W. 40th St., New York, N. Y. (49).

BLOUNT, HENRY FITCH, "The Oaks," Washington, D. C. (32). B I

Boas, Emil L., 37 Broadway, New York, N. Y. (50). I

*Boas, Dr. Franz, Am. Mus. Nat. History, Central Park, New York, N. Y. (36). 1888. H I

*Bodine, Prof. Donaldson, Wabash College, Crawfordsville, Ind. (45). 1899. E F

*Bogert, Marston Taylor, Havenmeyer Hall, Columbia Univ., New York, N. Y. (47). 1900. C

Boggs, Lemuel Stearns, care Sargent & Lundy, 1000 Isabella Bld'g, Chicago, Ill. (50). D

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*Bolley, Henry L., Agricultural College, North Dakota. (39). 1892. G

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*Bolton, Thaddeus L., Ph. D., Dept. Philosophy, University of Nebraska, Lincoln, Neb. (50). 1901. H I

Bond, Fred, State Engineer, Cheyenne, Wyoming. (50). D

*Bond, Geo. M., The Pratt & Whitney Co., Hartford, Conn. (33). 1885. D

Bond, R. I., M. D., Hartshorne, Ind. Ter. (50). K

*Bookman, Samuel, Ph. D., 9 E. 62nd St., New York, N. Y. (47). 1900. C

Boon, John Daniel, Professor of Physics, Chemistry and Geology, John Tarleton College, Stephenville, Texas. (50). B C E

Booraem, J. V. V., 204 Lincoln Place, Brooklyn, N. Y. (36).

Booth, Edward, Instructor in Chemistry, Univ. of California, Berkeley, Cal. (50). C

*Booth, Miss Mary A., 60 Dartmouth St., Springfield, Mass. (34). 1894. F G I

Bossi, Arnold L., Ph. D., Chemist and Colorist, Manchester Mills, Manchester, N. H. (50). C

Boston, L. Napoleon, M. D., 1531 S. Broad St., Philadelphia, Pa. (51). K

Boucek, Anthony J., M. D., 624 Chestnut St., Allegheny, Pa. (51). K

*Bouscaren, Louis Frederic Gustav, Chief Enigneer, Water Works Commission, City Hall, Cincinnati, Ohio. (50). 1901. D

*Bouton, Charles Leonard, Instructor in Mathematics, Harvard University, Cambridge, Mass. (50). 1901. A.

Boutwell, John Mason, U. S. Geol. Survey, Washington, D. C. (46). E

*Bowditch, Charles P., 28 State St., Boston, Mass. (43). 1897. H

Bowditch, Miss Charlotte, Pond St., Jamaica Plain, Mass. (50). I

*Bowditch, Prof. H. P., Jamaica Plain, Mass. (28). 1880. B F H

Bowker, R. R., 28 Elm St., New York, N. Y. (43). B

Bowlus, E. Lingan, Professor of Biology, Mt. Union College, Alliance, Ohio. (50). F

Bowman, Charles Henry, Professor of Mechanics and Electrical Engineering, State School of Mines, Butte, Mont. (51). D

Bowman, Joseph H., Resident Engineer, Vera Cruz and Pacific Ry., Apartado 21, Cordoba, Mexico. (50). D

Bownocker, Prof. J. A., Ohio State University, Columbus, Ohio. (48). E

*Bowser, Prof. E. A., Rutgers College, New Brunswick, N. J. (28). 1881.

*Boyd, James E., Ohio State Univ., Columbus, Ohio. (46). 1899. **B**
*Boye, Martin H., M. D., Coopersburg, Pa. (1). 1896. **C**
*Brace, Prof. D. B., Univ. of Nebraska, Lincoln, Neb. (48). 1900.
Brackenridge, George W., San Antonio, Texas, (41). **I**
Brackett, Byron B., Ph. D., Rutgers College, New Brunswick, N. J. (46). **B**
*Brackett, Prof. C. F., Princeton University, Princeton, N. J. (19). 1875. **B**
Brackett, Frank Parkhurst, Professor of Mathematics, Pomona College, Claremont, Cal. (50). **A**
*Brackett, Richard N., Clemson College, S. C. (37). 1891. **C E**
Bradford, Prof. Joseph N., Ohio State Univ., Columbus, Ohio. (48).
*Bradford, Royal B., Commander, U. S. N., Navy Dept., Washington, D. C. (31). 1891. **B D**
Bradley, Arthur C., Newport, N. H. (43).
Bradley, Charles S., 44 Broad St., New York, N. Y. (40).
Bradley, Charles Whiting, 1064 Ellicott Square, Buffalo, N. Y. (51). **D**
Bradley, Milton, Springfield, Mass. (44). **B**
Bradley, M. J., 373 Fulton St., Brooklyn, N. Y. (43).
Bradley, Walter Parke, Ph. D., Professor of Chemistry, Wesleyan University, Middletown, Conn. (50). **C**
Bramwell, Geo. W., 335 Broadway, New York, N. Y. (43). **D**
*Branner, Prof. John C., Stanford University, Cal. (34). 1886. **E F**
Brasefield, Stanley E., Instructor in Mathematics, Lafayette College, Easton, Pa. (50). **A**
*Brashear, John A., Allegheny, Pa. (33). 1885. **A B D**
Brassill, Miss Sarah Ellen, South Weymouth, Mass. (47). **F G**
Braunnagel, Jules L. A., M. D., P. O. Box 925, San Antonio, Texas. (50). **F**
*Bray, William L., Professor of Botany, Univ. of Texas, Austin, Texas. (49). 1901. **G**
Brayton, Sarah H., M. D., The Hereford, Evanston, Ill. (33).
Brett, George P., Darien, Conn. (49).
Brewer, Charles Edward, Professor of Chemistry, Wake Forest College, Wake Forest, N. C. (50). **C**
*Brewer, Prof. Wm. H., 418 Orange St., New Haven, Conn. (20). 1875. **E F I**
Brewster, Edwin Tenney, Instructor in Natural Sciences, Phillips Academy, Andover, Mass. (51).
Brewster, Frank H., M. E., Birmingham Iron Foundry, P. O. Box 418, Derby, Conn. (51). **D**
Brice, Judge Albert G., 901 Hennen Bldg., New Orleans, La. (32). **H**
Bridge, Norman, M. D., 100 Grand Ave., Pasadena, Cal. (51). **K**

Briggs, Edward Cornelius, Harvard Medical School, Boston, Mass. (50). **F K**

*Briggs, Lyman J., U. S. Dept. Agriculture, Washington, D. C. (48). 1901. **B**

Briggs, Wallace Alvin, M. D., 1300 I St., Sacramento, Cal. (51). **K**

*Brigham, Albert Perry, Professor of Geology, Colgate Univ., Hamilton, N. Y. (41). 1900. **E**

Brill, George M., Consulting Engineer, 1134 Marquette Building, Chicago, Ill. (51). **D**

Bristol, John I. D., 1 Madison Ave., New York, N. Y. (49).

*Bristol, Wm. H., Stevens Institute, Hoboken, N. J. (36). 1894. **A B D**

*Britton, N. L., Ph. D., N. Y. Botanical Garden, Bronx Park, New York, N. Y. (29). 1882. **E G**

Britton, Wiley, Special Pension Examiner, Springfield, Mo. (40). **F**

Brodie, Paul Thomas, Professor of Mathematics, Clemson College, Clemson College, S. C. (50). **A**

Bronson, Dr. E. B., 123 W. 34th St., New York, N. Y. (49).

Brooks, Albert A., High School, Kansas City, Kan. (50). **F G**

Brooks, Rev. Earle Amos, 161 Laidley St., Charleston, W. Va. (50). **F**

Brooks, Morgan, Professor of Electrical Engineering, Univ. of Illinois, Urbana, Ill. (50). **D**

Brooks, Prof. Wm. P., Amherst, Mass. (38). **C F**

*Brooks, Wm. R., D. Sc., Director Smith Observatory, Geneva, N. Y. (35). 1886. **A B D G**

Brown, Amos Peaslee, Ph. D., Assistant Professor of Geology and Mineralogy, Univ. of Pennsylvania, Philadelphia, Pa. (50). **E**

Brown, Arthur Erwin, Secy. Zoological Society of Philadelphia, 1208 Locust St., Philadelphia, Pa. (51). **F**

Brown, Elisha Rhodes, President Stafford Savings and National Banks, 50 Silver St., Dover, N. H. (50). **I**

Brown, George S., M. D., 2220 1st Ave. Birmingham, Ala. (51). **K**

Brown, Glenn V., Bradford, Pa. (51). **B C E**

Brown, Harold W., Lehigh Univ., So. Bethlehem, Pa. (48). **B C**

BROWN, JOSEPH STANFORD, 241 S. 5th St., Reading Pa. (50). **D**

Brown, Newton H., Delaware College, Newark, Delaware. (48). **B D**

Brown, Philip King, M. D., 1303 Van Ness Ave., San Francisco, Cal. (51). **K**

*Brown, Robert, Yale University Observatory, New Haven, Conn. (11). 1874. **A**

*Brown, Mrs. Robert, Observatory Place, New Haven, Conn. (17). 1874.

Brown, Robert Marshall, 68 Kirkland St., Cambridge, Mass. (48).

Brown, Samuel B., Morgantown, W. Va. (40). **E**

Brown, Stewardson, Germantown, Pa. (50). **I**

Brown, S. J., U. S. Naval Academy, Annapolis, Md. (49). **A**
Brown, W. L., 42 West 72d St., New York, N. Y. (50). **I**
Brownell, Silas B., 71 Wall St., New York, N. Y. (36).
Browning, Charles Clifton, M. D., Highland, Cal. (51). **K**
Browning, Philip Embury, Kent Chemical Laboratory, Yale University, New Haven, Conn. (46). **C**
Bruggerhof, F. W., 36 Cortlandt St., New York, N. Y. (49).
*Brühl, Gustav, cor. John and Hopkins Sts., Cincinnati, Ohio. (28). 1886. **H**
Brundage, Albert H., M. D., 1153 Gates Ave., Brooklyn, N. Y. (43). **F G H**
Bruner, Henry Lane, Ph. D., Professor of Biology, Butler College, Indianapolis, Ind. (50). **F**
*Bruner, Lawrence, Professor of Entomology, Univ. of Nebraska, Lincoln, Neb. (50). 1901. **F**
BRUNTON, DAVID WILLIAM, Mining Engineer, 865 Grant Ave., Denver, Colo. (50). **D E**
*Brush, Charles F., 1003 Euclid Ave., Cleveland, Ohio. (35). 1886. **B**
*BRUSH, PROF. GEORGE J., Yale Univ., New Haven, Conn. (4). 1874. **C E**
*Bryan, Prof. William L., Indiana Univ., Bloomington, Ind. (49). 1900. **H**
Bryant, Miss D. L., 218 Ashe St., Greensboro, N. C. (42.) **E**
Bryant, Henry G., 2013 Walnut St., Philadelphia, Pa. (51). **E**
Bryson, Andrew, C. E., Brylgon Foundry, Reading., Pa. (51). **D**
Buchanan, James Isaac, Vice-President Pittsburg Trust Co., 6108 Walnut St., Pittsburg, Pa. (51). **I**
Buchholz, Carl Waldemar, Chief Engineer, Erie R.R. Co., 21 Cortlandt St., New York, N. Y. (51). **D E**
*Buchner, Edward Franklin, Clark University, Worcester, Mass. (49). 1901. **H**
*Buckhout, W. A., State College, Pa. (20). 1881. **F**
Buckingham, Charles L., 195 Broadway, New York, N. Y. (28).
Buffum, Burt C., Professor of Agriculture, Agricultura College, Fort Collins, Colo. (42). **G**
Buist, John Robinson, M. D., City Board of Health, Nashville, Tenn. (50). **K**
*Bull, Prof. Storm, University of Wisconsin, Madison, Wis. (44). 1897. **D**
Bullard, Warren Gardner, Ph. D., Associate Professor of Mathematics, Syracuse University, Syracuse, N. Y. (50). **A**
Bullene, Mrs. Emma F. Jay, 1431 Court Place, Denver, Colo. (50). **H**
*Bumpus, H. C., Am. Mus. Nat. Hist., New York, N. Y. (49). 1900.

Bunker, Henry A., M. D., 158 Sixth Ave., Brooklyn, N. Y. (50). **I**
Bunn, J. F., Attorney at Law, Tiffin, Ohio, (51). **B**
*Burbank, Luther, Santa Rosa, Cal. (50). 1901. **G**
Burbidge, Frederick, 510 Empire State Building, Spokane, Wash. (50). **D E**
Burdell, W. J., M. D., Lugoff, S. C., (51). **K**
*Burgess, Edward S., 11 W. 88th St., New York, N. Y. (47). 1901. **G**
*Burgess, Dr. Thomas J. W., Medical Supt. Protestant Hospital for the Insane, Montreal, Can. (38). 1889. **G**
Burgwyn, Collinson Pierrepont Edwards, Civil and Consulting Engineer, 819 Main St., Richmond, Va. (51). **D**
Burke, M. D., C. E., 404 Pike Bldg., Cincinnati, Ohio. (50). **A B C D E**
Burke, Robert E., Instructor in Chemistry, Mechanic Arts High School, Boston, Mass. (50). **C**
Burnham, Edward J., Manchester, N. H. (47). **F**
Burnham, George, Jr., C. E., Burnham, Williams & Co., Baldwin Locomotive Works, 214 N. 34th St. Philadelphia, Pa. (51). **D**
*Burr, Prof. William H., Columbia University, New York, N. Y. (31). 1883.
Burrell, Herbert Leslie, M. D., 22 Newbury St., Boston, Mass. (51). **K**
Burroughs, Paul R., 1160 27th St., Des Moines, Iowa. (50). **C**
*Burt, Edward Angus, Ph. D., Professor of Natural History, Middlebury College, Middlebury, Vt. (50). 1901. **G**
Burton, Prof. Alfred E., Mass. Inst. Technology, Boston, Mass. (40). **E**
Burton, Standish Barry, Civil and Mining Engineer, Saltillo, Coahuila, Mexico. (51). **D**
Busch, Frederick Carl, M. D., 145 Allen St., Buffalo, N. Y. (49).
Bush-Brown, Henry Kirke, Sculptor, Newburgh, N. Y. (50). **E I**
Bush, John C. F., M. D., Wahoo, Neb. (51). **K**
*Butler, Amos W., Secretary Board of State Charities, Indianapolis, Ind. (30). 1885. **F H**
Butler, Frank Edward, President of Grayson College, Whitewright, Texas. (50). **I**
Butler, Matthew Joseph, Civil Engineer, Charlottetown, Prince Edward Island, Canada. (51). **D**
Butterfield, Arthur Dexter, Assistant Professor of Mathematics, University of Vermont, Burlington, Vt. (50). **A D**
Butterworth, Irvin, Denver Gas and Electric Co., Denver, Colo. (50). **B**
Butts, Edward Pontany, C. E., Chief Engineer, Am. Writing Paper Co., Holyoke, Mass. (51). **D**
Byrnes, Owen, Mining Engineer, P. O. Box 131, Marysville, Montana. (51). **D E**

Cabot, Samuel, Manufacturing Chemist, 70 Kilby St., Boston, Mass. (50). **C**

Cady, Walter G., Ph. D., 127 Power St., Providence, R. I. (49). **B**

*Cain, William, Professor of Mathematics, University of North Carolina, Chapel Hill, N. C. (50). 1901. **A D**

*Cajori, Florian, Professor of Mathematics, Colorado College, Colorado Springs, Colo. (50). 1901. **A**

Calder, George, 105 East 22d St., New York, N. Y. (50).

*Caldwell, Prof. Francis C., Ohio State University, Columbus, Ohio. (46). 1898. **B D**

*Caldwell, Prof. George C., Cornell University, Ithaca, N. Y. (23) 1875. **C**

Caldwell, Prof. Otis W., State Normal School, Charleston, Ill. (49). **G**

*Calkins, Gary N., Columbia University, New York, N. Y. (49). 1901. **F**

Calkins, Marshall, M. D., 14 Maple St., Springfield, Mass. (29).

Calvert, Philip P., Ph. D., Instructor in Zoology, Biological Hall, University of Pennsylvania, Philadelphia, Pa. (50). **F**

Calvert, Prof. Sidney, Univ. of Missouri, Columbia, Mo. (47). **C**

*Calvin, Prof. Samuel, Dir. Iowa Geol. Surv., Iowa City, Iowa.. (37). 1889. **E F**

Came, Virgil M., 315 Quincy Building, Denver, Colo. (50). **E**

*Cameron, Frank K., Ph. D., Chemist, Bureau of Soils, U. S. Dept. Agriculture, Washington, D. C. (49). 1901. **C**

Cammann, Hermann H., 43 W. 38th St., New York, N. Y. (49).

*Campbell, Douglas H., Professor of Botany, Stanford University, Cal. (34). 1888. **G**

Campbell, Leslie Lyle, Ph. D., Westminster College, Fulton, Mo. (48).

*Campbell, William Wallace, Director of Lick Observatory, Mt. Hamilton, Cal. (50). 1901. **A**

*Canby, William M., 1101 Delaware Avenue, Wilmington, Del. (17). 1878. **G**

*Cannon, George Lyman, Instructor in Geology, Denver High School (No. 1), Denver, Colo. (39). 1901. **E**

Card, Fred. W., Kingston, R. I. (45). **G**

Carey, Everett P., Redwood City, Cal. (50). **B C**

Cargill, Geo. W., Attorney at Law, Charleston, W. Va. (51). **B D F G**

*Carhart, Prof. Henry S., Univ. of Michigan, Ann Arbor, Mich. (29). 1881. **B**

*Carleton, M. A., U. S. Dept. Agriculture, Washington, D. C. (42). 1894. **G**

Carnaghan, Edwin Dixon, Mechanical Engineer, Durango, Do, Mexico. (50). **D**

Carnahan, Charles T., Mining Engineer, Equitable Building, Denver, Colo. (50). **D E**

Carnegie, Thomas Morrison, Trustee of Carnegie Institute, Dungeness, Fernandina, Fla. (50). **F**

Carnell, Frederic J., Assistant in Physics, Sheffield Scientific School, New Haven, Conn. (50). **B**

Carpenter, Ford A., U. S. Weather Bureau, San Diego, Cal. (44). **D**

Carpenter, Franklin R., Ph. D., Mining Expert, 1420 Josephine St. Denver, Colo. (50). **D E**

*Carpenter, Louis G., Agric. College, Fort Collins, Colo. (32). 1889. **A B**

Carr, William Phillips, M. D., 1418 L St. N.W., Washington, D. C. (51). **K**

Carroll, James, M. D., 910 23d St., N.W., Washington, D. C. (50). **F K**

Carroll, James J., Waco, Texas. (50). **F**

Carson, Shelby Chadwick, M. D., Greensboro, Ala. (51). **K**

Carss, Miss Elizabeth, Teachers' College, New York, N. Y. (49). **G**

Carter, Henry C., 475 West 143d St., New York, N. Y. (50).

Carter, James, M. D., Carbon, Wyoming. (50). **E K**

CARTER, JAMES C., 277 Lexington Ave., New York, N. Y. (36).

*Carter, James Madison G., M. D., Waukegan, Ill. (39). 1895. **F**

Carter, John E., Knox and Coulter Sts., Germantown, Pa. (33). **B H**

Carter, Marion H., Fiske Hall, Barnard College, New York, N. Y. (49).

Carter, William Harrison, Stone Mountain, Ga. (50). **A**

*Carus, Paul, Ph. D., Editor Open Court Pub. Co., 324 Dearborn St., Chicago, Ill. (40). 1895. **H**

Cary, Albert A., 95 Liberty St., New York, N. Y. (36). **D**

Cary, Mrs. Elizabeth M. L., 184 Delaware Ave., Buffalo, N. Y. (45). **E**

Case, Eckstein, Case School of Applied Science, Cleveland, Ohio. (47).

Case, Ermine Cowles, Prof. of Chemistry and Geology, State Normal School, Milwaukee, Wis. (50). **B C E**

*Casey, Thomas L., Major of Engineers, U. S. A., P. O. Drawer 71, St. Louis, Mo. (38). 1892. **D F**

Caswell, W. H., M. D., 201 West 55th St., New York, N. Y. (50).

Cathcart, Miss J. R., The Barnard, 71st St. and Central Park, New York, N. Y. (50).

*Catlin, Charles A., 133 Hope St., Providence, R. I. (33). 1895. **C**

Catt, George William, C. E., President, Atlantic, Gulf and Pacific Co., Park Row Building, New York, N. Y. (51). **D**

*Cattell, H. W., M. D., 3709 Spruce St., Philadelphia, Pa. (50). 1901. **K**

*CATTELL, PROF. JAMES MCKEEN, Columbia Univ., New York, N. Y. (44). 1896. **B F H I**

Chadwick, Leroy S., 1824 Euclid Ave., Cleveland, Ohio. (51).

Chaillé, Stanford E., M. D., LL.D., Dean of Medical Department, Tulane University, New Orleans, La. (51). **K**

*Chamberlain, Charles Joseph, Dept. of Botany, University of Chicago, Chicago, Ill. (50). 1902. **G**

Chamberlain, Frederic M., U. S. Fish Commission, Washington, D. C. (51). **F**

Chamberlain, Paul Mellen, Prof. of Mechanical Engineering, Lewis Institute, Chicago, Ill. (51). **D**

Chamberlin, Rollin Thomas, Hyde Park Hotel, Chicago, Ill. (50). **C E**

*Chamberlin, T. C., Head of Dept. of Geology, Univ. of Chicago, Chicago, Ill. (21). 1877. **B E F H**

Chamberlin, W. E., Ph. D., 111 Water St., New York, N. Y. (50).

Chambers, Frank R., 569 Broadway, New York, N. Y. (50).

*Chandler, Prof. C. F., School of Mines, Columbia University, New York, N. Y. (19). 1875. **C**

*Chandler, Prof. Charles Henry, Ripon, Wis. (28). 1883. **A**

Chandler, Elwyn Francis, Instructor in Mathematics, University of North Dakota, University, N. Dak. (50). **A B**

Chandler, Richard E., Stillwater, Oklahoma. (46). **B D**

*Chandler, Seth C., 16 Craigie St., Cambridge, Mass. (29). 1882. **A**

Chaney, Prof. Lucian W., Carleton College, Northfield, Minn. (45).

Channing, Walter, M. D., Brookline, Mass. (50). **I K**

*Chanute, O., 413 E. Huron St., Chicago, Ill. (17). 1877. **D I**

Charlton, Orlando Clarke, Professor, Biology and Geology, Baylor University, Waco, Tex. (51). **E F G**

*Chase, Frederick L., Yale University Observatory, New Haven, Conn. (43). 1896. **A**

Chase, R. Stuart, 53 Summer St., Haverhill, Mass. (18). **F**

*Chauvenet, Wm. M., Mining Engineer, 620 Chestnut St., St. Louis, Mo. (50). 1901. **C D**

*Cheesman, T. M., M. D., Garrison-on-Hudson, N. Y. (50) 1901. **K**

Cheney, Mrs. B. P., Sr., Wellesley, Mass. (51).

Cheney, Mrs. Ednah Dow, Jamaica Plain, Mass. (47).

*Cheney, Lellen Sterling, 318 Bruen St., Madison, Wis. (42). 1894. **G**

Cheney, Willard Colfax, Electrical Engineer, Portland, Oregon. (50). **D**

*Chester, Prof. Albert H., Rutgers College, New Brunswick, N. J. (29). 1882. **C F**

*Chester, Colby M., Captain, U. S. N., Navy Dept., Washington, D. C. (28). 1897. **E**

Chester, Wayland Morgan, Associate Professor of Biology, Colgate University, Hamilton, N. Y. (50). **F**

*Chickering, J. W., The Portner, Washington, D. C. (22). 1877. **G I**

Chilcott, Ellery Channing, Professor of Geology, Agricultural College, Brookings, S. D. (50). **E**

*Child, Charles Manning, Instructor in Zoology, University of Chicago, Chicago, Ill. (50). 1901. **F**

*Child, Clement D., Colgate Univ., Hamilton, N. Y. (44). 1899. **B**

Childs, Arthur Edward, V. P. and Treas. the Light, Heat and Power Corporation, 23 Central St., Boston, Mass. (50). **B D I**

Childs, James Edmund, Civil Eng., 300 W. 93d St., New York, N. Y. (51). **D**

Chisholm, Hugh J., 813 Fifth Avenue, New York, N. Y. (50).

Chisolm, George E., 19 Liberty St., New York, N. Y. (50).

*Chittenden, Frank Hurlbut, U. S. Dept. Agriculture, Washington, D. C. (48). 1901. **F**

*Chittenden, Russell H., Director of Sheffield Scientific School, Yale University, New Haven, Conn. (50). 1901. **C F**

Chittenden, Thomas A., Instructor in Mechanical Engineering, A. and M. College, W. Raleigh, N. C. (50). **D**

*Christie, James, Chief Mech. Engineer Am. Bridge Co., Pencoyd, Pa. (33). 1894. **D**

Chrystie, Wm. F., Hastings-on-Hudson, New York, N. Y. (36).

Church, E. D., Jr., 63 Wall St., New York, N. Y. (50).

Church, Royal Tyler, Turin, N. Y. (38). **D F**

Church, Samuel H., Secretary, Carnegie Institute, 1003 Penn Ave., Pittsburg, Pa. (51). **D I**

*Chute, Horatio N., Instructor in Physical Sciences, High School, Ann Arbor, Mich. (34). 1889. **A B C**

*CILLEY, FRANK H., Mass. Inst. Technology, Boston, Mass. (49). 1901. **A B D**

Clancy, Michael Albert, 1426 Corcoran St., Washington, D. C. (40). **H**

Clapp, Frederick Gardner, 169 Boston St., South Boston, Mass. (51). **E**

Clark, Alexander S., Westfield, N. J. (33).

Clark, Mrs. Alfred Corning, 347 W. 89th St., New York, N. Y. (49).

Clarke, Miss Cora H., 91 Mt. Vernon St., Boston, Mass. (47). **F G**

Clark, Edmund, 426 Sanford Ave., Flushing, L. I., N. Y. (50).

Clark, Edward, 417 Fourth St., N.W., Washington, D. C. (40).

Clark, Ernest P., 229 W. 18th St., New York, N. Y. (50). 1901. **D**

Clark, Friend Ebenezer, New Martinsville, W. Va. (51). **C**

*Clarke, Prof. F. W., U. S. Geol. Survey, Washington, D. C. (18). 1874. **C**

*Clark, Gaylord Parsons, Professor of Physiology, Syracuse University, Syracuse, N. Y. (50). 1901. **F K**

Clark, Herbert A., Haskell Institute, Lawrence, Kansas. (50). **B C**

Clark, Hubert Lyman, Ph. D., Professor of Biology, Olivet College, Olivet, Mich. (50). **F**

Clark, James Frederick, M. D., Fairfield, Iowa. (50). **I K**

*Clark, Prof. John E., 445 Orange St., New Haven, Conn. (17). 1875. **A**

Clark, John Jesse, Dean of Faculty, International Correspondence Schools, Scranton, Pa. (50). **B D**

*Clarke, John Mason, Ph. D., Asst. State Geologist and Palæontologist, State Hall, Albany, N. Y. (45). 1897. **E**

*Clark, John S., 110 Boylston St., Boston, Mass. (31). 1901. **B C I**

Clark, Joseph E., M. D., 396 Fourth St., Brooklyn, N. Y. (43). **A E**

Clark, Oliver Durfee, 590 Halsey St., Brooklyn, N. Y. (41). **E F**

*Clarke, Prof. Samuel Fessenden, Williams College, Williamstown, Mass. (50). 1901. **F**

Clark, Thomas H., Box 166, Plymouth, N. H. (40).

Clark, Wm. Brewster, M. D., 50 E. 31st St., New York, N. Y. (33). **C F**

*Clark, Wm. Bullock, Ph. D., Johns Hopkins University, Baltimore, Md. (37). 1891. **E**

*Claypole, Dr. Agnes M., Pasadena, Cal. (46). 1899. **F**

*Claypole, Miss Edith J., Pasadena, Cal. (46). 1899. **F**

Cleaver, Albert N., South Bethlehem, Pa. (50). **D**

Cleburne, William, 1219 So. Sixth St., Omaha, Neb. (51). **G**

Clerc, Frank L., Professor of Metallurgy and Assaying, Colorado State School of Mines, Hotel Metropole, Denver, Colo. (50). **C D**

Clifton, Richard S., Assistant Secretary, A. A. A. S., Washington, D. C. (49). **F**

Cline, Isaac M., M. D., U. S. Weather Bureau, New Orleans. La. (50). **K**

*Cloud, John W., 974 Rookery, Chicago, Ill. (28). 1886. **A B D**

Clough, Albert L., Box 114, Manchester, N. H. (45). **B**

Coates, Charles E., Ph. D., Louisiana State Univ., Baton Rouge, La. (46). **C**

Cobb, Arthur, Architect, 600 Equitable Building, Louisville, Ky. (50). **D**

Cobb, Prof. Collier, University of North Carolina, Chapel Hill, N. C. (49).

*Cochran, C. B., 514 South High St., West Chester, Pa. (43). 1896. **C**

*Cockerell, T. D. A., Consulting Entomologist, N. M. Agric. Exper. Station, East Las Vegas, New Mexico. (50). 1901. **F**

Cockran, Hon. W. Bourke, 31 Nassau St., New York, N. Y. (50).
COE, HENRY W., M. D., "The Marquam," Portland, Oregon. (32). **F H**
Coe, Thomas Upham, M. D., Bangor, Maine, (51) **K**
Coffeen, Hon. H. A., Sheridan, Wyoming. (51).
Coffin, C. A., 44 Broad St., New York, N. Y. (50).
*Coffin, Selden J., Ph. D., Lafayette College, Easton, Pa. (22). 1874. **A I**
*Cogswell, Wm. B., Syracuse, N. Y. (33). 1891. **D**
Cohen, Mendes, Civil Engineer, 825 N. Charles St., Baltimore, Md. (50). **D**
Cohen, Solomon Solis, M. D., 1525 Walnut St., Philadelphia, Pa. (50). **F K**
Coit, Joseph Howland, Saint Paul's School, Concord, N. H. (50).
Coit, J. Milner, Ph. D., Saint Paul's School, Concord, N. H. (33). **B C E**
*COLBURN, RICHARD T., Elizabeth, N. J. (31). 1894. **F H I**
Colby, Edward A., 128 Lincoln Ave., Newark, N. J. (49).
*Cole, Prof. Alfred D., Ohio State Univ., Columbus, Ohio. (39). 1891. **B C**
Cole, W. F., M. D., Waco, Texas. (51) **K**
Coleman, Clarence, U. S. Assistant Engineer, Duluth, Minn. (51). **D H**
Coleman, Walter, Prof. of Natural History, Sam Houston Normal Institute, Huntsville, Texas. (51). **K**
Colgate, Abner W., Morristown, N. J. (44).
Colie, Edw. M., East Orange, N. J. (30). **E I**
Collett, Samuel Williamson, Principal of High School, Urbana, Ohio. (50). **G**
Collier, Price, Tuxedo Park, N. Y. (50).
*Collin, Prof. Alonzo, Cornell College, Mount Vernon, Iowa. (21). 1891. **B C**
Collin, Rev. Henry P., 58 Division St., Coldwater, Mich. (37). **H**
*Collingwood, Francis, Elizabeth, N. J. (36). 1888. **D**
Collins, T. Shields, M. D., Globe, Arizona. (51). **K**
Colton, Geo. H., Professor of Natural Science, Hiram College, Hiram, Ohio. (51). **B E**
*Colvin, Verplanck, Supt. N. Y. State Adirondack Survey, Albany, N. Y. (28). 1880. **E**
*Comstock, Prof. Charles Worthington, State School of Mines, Golden, Colo. (47). 1901. **A D**
*Comstock, Prof. Geo. C., Washburn Observatory, University of Wisconsin, Madison, Wis. (34). 1887. **A**
*COMSTOCK, PROF. THEO. B., Mining and Metallurgical Engineer, 534 Stinson Bldg., Los Angeles, Cal. (24). 1877. **B D E**
Comstock, Dr. T. Griswold, 3401 Washington Ave., St. Louis, Mo. (29). **F H**

Conant, Miss E. Ida, 42 W. 48th St., New York, N. Y. (33). **F H I**

*Conant, Prof. Levi L., Polytechnic Institute, Worcester, Mass. (39). 1892. **A**

Conarroe, Thomas H., M. D., Lecturer on Biology, Hahnemann Medical College of Philadelphia, Philadelphia, Pa. (50). **F K**

*Conklin, Edwin Grant, Professor of Biology, University of Pennsylvania, Philadelphia, Pa. (50). 1901. **F**

Connelley, C. B., Supervisor Industrial Schools, Allegheny, Pa. (49). **I**

Connor, Leartus, M. D., President of Michigan State Medical Society, 103 Cass St., Detroit, Mich. (51). **K**

Conradson, Pontus H., Chief Chemist, Galena-Signal Oil Co., Franklin, Pa. (51). **B C D**

Constant, Frank H., Professor of Structural Engineering, University of Minnesota, Minneapolis, Minn. (51). **D.**

Converse, Vernon G., 15th St. and Liberty Ave., Pittsburg, Pa. (50). **D**

Conway, George M., Mechanical Engineer, 10 Belvedere, Milwaukee, Wis. (51). **D**

Cook, Dr. Charles D., 162 Remsen St., Brooklyn, N. Y. (25).

Cooke, George Willis, Park St., Wakefield Park, Wakefield, Mass. (47). **H I**

Cook, James B., Randolph Building, Memphis, Tenn. (50).

Cook, Melville T., Greencastle, Ind. (45). **G**

*Cook, Orator F., U. S. Dept. of Agriculture, Washington, D. C. (40). 1892. **G**

Cook, Samuel R., Professor of Physics and Chemistry, Washburn College, Topeka, Kansas. (50). **B C**

*Cooley, Grace E., Ph. D., Wellesley College, Wellesley, Mass. (47). 1900. **G I**

*Cooley, Prof. LeRoy C., Vassar College, Poughkeepsie, N. Y. (19). 1880. **B C**

*Cooley, Prof. Mortimer E., University of Michigan, Ann Arbor, Mich. (33). 1885. **D**

Cooley, Robert A., Zoologist and Entomologist, Montana Agr'l College and Experiment Station, Bozeman, Montana. (50). **F**

Cooper, Hon. Edward, 12 Washington Square, N., New York, N. Y. (49).

Cooper, James Campbell, Room 5, Veale Block, Topeka, Kansas. (50). **C E**

*Copeland, Edwin Bingham, 653 E. 57th St., Chicago, Ill. (45). 1901. **G**

*Coquillett, Daniel William, U. S. National Museum, Washington, D. C. (43). 1902. **F**

*Corbett, L. C., U. S. Dept. Agriculture, Washington, D. C. (48). 1901. **G**

Cornman, Oliver P., Ph. D., 2252 N. 20th St. [illegible]
B

*Corthell, Elmer L., 1 Nassau St., New York, N. Y. [illegible]
D E I

Corwin, Clifford Egbert, Teacher of Science. [illegible]
Marietta, Ohio. (50). C

Coster, William H., Chemist and Biologist [illegible]
Department of Public Works, Pittsburg, Pa. [illegible]

*Coulter, Prof. John M., University of Chicago [illegible]
(32). 1884. G

Curtis, William Munroe, 412 Hammond Bldg. [illegible]
(46). E C G

Coutant, Richard Bonnet, M. D., Tarrytown, N. Y. [illegible]

*Coville, Frederick V., U. S. Dept. Agriculture, Washington [illegible]
(35). 1890. G

Cowell, John F., Botanic Garden, West Seneca, N. Y. [illegible]

*Cowles, Alfred H., 656 Prospect St., Cleveland, Ohio [illegible]
B C

Cowles, Miss Louise F., Mt. Holyoke College, South Hadley, Mass.
(47). E

Cox, Abraham Beekman, Civil Engineer, Cherry Valley, N. Y.
(50). D

*Cox, Charles F., Grand Central Depot, New York, N. Y. [illegible]
1900. F G

Cox, Edmund Otis, C. E., Manhattan Railway Co., 11 Manhattan
Ave., New York, N. Y. (51). D

Cox, John, Professor of Experimental Physics, McGill University,
Montreal, Can. (51). B

Cox, Ulysses O., Professor of Biology, State Normal School, Mankato,
Minn. (50). F

[illegible] Buckley B., Jr., U. S. Weather Bureau Observer, Drifton, Pa.
[illegible]

[illegible] Rev. John S., S. J., St. Joseph's College, 17th and Stiles Sts.,
Philadelphia, Pa. (48). B

Crafts, Clayton Edward, 5433 Washington Boulevard, Chicago, Ill.
(50). I

*Crafts, James Mason, Mass. Inst. Technology, Boston, Mass. (47).
1898. C

*Cragin, Francis Whittemore, Ph. D., 1715 Wood Ave., Colorado
Springs, Colo. (29). 1890. E F H

Craig, Alexander Righter, M. D., 232 Cherry Street, Columbia,
Pa. (51). K

Craig, John, College of Agriculture, Cornell University, Ithaca,
N. Y. (41). G

Craig, Wallace, Zoological Laboratory, Univ. of Chicago, Chicago,
Ill. (50). F

CRAM, ROYS JONES, 26 Hancock Ave., West, Detroit, Mich. (51).

*Crampton, Chas. A., M. D., Office of Internal Revenue Commissioner, U. S. Treasury Dept., Washington, D. C. (36). 1887. C

Crampton, Henry E., Adjunct Professor of Zoology, Barnard College, Columbia University, New York, N. Y. (51). F

*Crandall, Charles S., Glendale, Cal. (40). 1894.

Crandall, Francis Asbury, 2219 15th St., N.W., Washington, D. C. (50). I

Crane, James M., Board of Education, Newburgh, N. Y. (50). I

Crane, Walter, Supt. Carnegie Free Library, Braddock, Pa. (47). G

Cranford, J. P., Wakefield, New York, N. Y. (50).

Cranston, Robert E., E. M., M'g'r Ashburton Mining Co., Folsom, Cal. (50). D E

Crawford, David Francis, Supt. Motive Power, Penna. Co., Ft. Wayne, Ind. (50). D

Crawford, John, Leon, Nicaragua, Central America. (40). E H

*Crawford, Morris B., Middletown, Conn. (30). 1889. B

*Crawley, Edwin S., Ph. D., Springfield Ave., Chestnut Hill, Philadelphia, Pa. (45). 1900. A

Crawley, Howard, Wyncote, Pa. (51). F

Crehore, Albert Cushing, Brookside Park, Tarrytown, N. Y. (50). D E

Crile, George W., M. D., 169 Kensington St., Cleveland, Ohio. (51). K

Crockard, Frank Hearne, E. M., C. E., Asst. Mgr. Riverside Dept. National Tube Co., Lock Box 34, Wheeling, W. Va. (50). D

*Crocker, Francis B., Professor of Electrical Engineering, Columbia University, New York, N. Y. (50). 1901. B D

*Crockett, Prof. Charles W., Rensselaer Polytechnic Institute, Troy, N. Y. (39). 1894. A D

Crook, Alja Robinson, Ph. D., 1914 Sheridan Road, Evanston, Ill. (47). E

*Crosby, Prof. W. O., Mass. Institute Technology, Boston, Mass. (47). 1900. E

*Cross, Prof. Charles R., Mass. Inst. Technology, Boston, Mass. (29). 1880. B

Crouse, Hugh Woodward, M. D., Victoria, Texas. (50). F K

CROWELL, A. F., Woods Holl, Mass. (30). C

*Crowell, John Franklin, Bur. of Statistics, Treasury Dept., Washington, D. C. (50). 1901. I

Crozier, William, Brigadier-General and Chief of Ordnance, U. S. A., War Department, Washington, D. C. (50). D

Cruikshank, James, LL.D., 206 S. Oxford St., Brooklyn, N. Y. (36).

Crump, Col. M. H., Bowling Green, Ky. (29). E

Cryer, Matthew H., M. D., D. D. S., 1420 Chestnut St., Philadelphia, Pa. (50). F K

*Culin, Stewart, Univ. of Pennsylvania, Philadelphia, Pa. (33). 1890. **H**

Culver, Charles Mortimer, M. D., 36 Eagle St., Albany, N. Y. (51). **K**

*Cumings, Edgar R., Bloomington, Ind. (48). 1901. **E**

*Cummings, Miss Clara E., Wellesley College, Wellesley, Mass. (47). 1899. **G**

Cummins, George Wyckoff, M. D., Belvidere, N. J. (50). **G K**

Cunningham, Francis A., 1613 Wallace St., Philadelphia, Pa. (33). **B D E**

*Cunningham, Prof. Susan J., Swarthmore College, Swarthmore, Pa. (38). 1901. **A**

Cuntz, Johannes H., 325 Hudson St., Hoboken, N. J. (36).

Currie, C. A., M. D., P. O. Box 1606, Philadelphia, Pa. (48). **F**

Curtis, Charles B., 9 East 54th St., New York, N. Y. (50).

Curtis, G. Lenox, M. D., 7 West 58th St., New York, N. Y. (51).

Curtis, Geo. W., McKinney, Texas. (50).

Curtis, H. Holbrook, M. D., 118 Madison Ave., New York, N. Y. (51). **K**

Curtis, Mattoon M., Prof. of Philosophy, Western Reserve University, Cleveland, Ohio. (50). **H I**

Curtis, William E., Post Building, Washington, D. C. (40). **H I**

*Cushing, Henry Platt, Adelbert College, Cleveland, Ohio. (33). 1888. **E**

Cushing, John J., 1001 Union Trust Bldg., Cincinnati, Ohio. (50). **D**

*Cushman, Allerton, Ph. D., Instructor in Chemistry, Bryn Mawr College, Bryn Mawr, Pa. (50). 1901. **C**

*Cushny, Arthur R., Professor of Materia Medica and Therapeutics, Univ. of Michigan, Ann Arbor, Mich. (50). 1901. **K**

Cutler, Colman Ward, M. D., 36 East 33d St., New York, N. Y. (50). **K**

Cutter, Ephraim, M. D., 120 Broadway, New York, N. Y. (51). **K**

Cutter, Irving S., Box 732, Lincoln, Neb. (50). **F G**

Cutter, W. D., College of Physicians and Surgeons, Columbia Univ., New York, N. Y. (50). **K**

*Dabney, Charles W., Ph. D., President University of Tennessee, Knoxville, Tenn. (47). 1901. **C**

Daggette, Alvin S., M. D., 400 South Craig St., Pittsburg, Pa. (50). **F K**

Dale, J. Y., M. D., P. O. Box 14, Lemont, Pa. (51). **K**

*Dall, William H., Smithsonian Institution, Washington, D. C. (18). 1874. **F H**

Dalrymple, W. H., Prof. Vet. Science, La. State Univ. and A. & M. College, Baton Rouge, La. (50). **F K**

*Dana, Dr. Charles L., 50 W. 46th St., New York, N. Y. (46). 1889. **H**

*Dana, Edward Salisbury, New Haven, Conn. (23). 1875. **B E**
Danforth, Isaac Newton, M. D., 70 State St., Chicago, Ill. (50). **K**
Daniel, John, Professor of Physics, Vanderbilt Univ., Nashville, Tenn. (50). **B**
Danielson, A. H., Agricultural College, Fort Collins, Colo. (50). **G**
*Darton, Nelson H., U. S. Geol. Survey, Washington, D. C. (37). 1893.
d'Auria, Luigi, M. E., 3810 Locust St., Philadelphia, Pa. (51). **A D**
*Davenport, Charles Benedict, Ph. D., Univ. of Chicago, Chicago, Ill. (46). 1898. **F**
Davenport, Eugene, Dean of the College of Agriculture, University of Illinois, Champaign, Ill. (39).
Davenport, Francis Henry, M. D., 419 Boylston St., Boston, Mass. (50). **K**
*Davidson, George, 2221 Washington St., San Francisco, Cal. (29). 1881. **A B D**
Davidson, R. J., Agric. Exper. Station, Blacksburg, Va. (40). **C**
Davies, William G., 22 E. 45th St., New York, N. Y. (49).
Davis, Abial B., 129 East Lincoln Ave., Mt. Vernon, N. Y. (44). **A**
Davis, Andrew McFarland, 10 Appleton St., Cambridge, Mass. (35). **H**
Davis, Bergen, Columbia University, New York, N. Y. (49). **B**
*Davis, Bradley Moore, Dept. of Botany, Univ. of Chicago, Chicago, Ill. (45). 1897. **G**
Davis, Charles F., Fort Collins, Colo. (50). **C**
*Davis, C. H., Commander U. S. N., Navy Dept., Washington, D. C. (40). 1896.
Davis, Edward E., 47 W. Main St., Norwich, N. Y. (50).
Davis, George S., P. O. Box 724, Detroit, Mich. (50).
*Davis, Herman S., Ph. D., Director of International Latitude Station, Gaithersburg, Md. (50). 1901. **A**
*Davis, J. J., M. D., 1119 College Ave., Racine, Wis. (31). 1899. **F G**
Davis, John J., Attorney at law, Clarksburg, W. Va. (50). **I**
Davis, J. Woodbridge, 523 West 173d St., New York. N. Y. (47). **A**
Davis, Kary Cadmus, Ph. D., Professor of Horticulture and Forestry, State University, Morgantown, W. Va. (50). **G**
Davis, Nathan Smith, M. D., LL. D., 65 Randolph St., Chicago, Ill. (51). **K**
Davis, N. S., Jr., 291 Huron St., Chicago, Ill. (50). **F G**
Davis, Wm. Harper, Asst. in Psychology, Columbia Univ., New York, N. Y. (50). **H I**
*Davis, Prof. Wm. Morris, Cambridge, Mass. (33). 1885. **B E**
Davis, Wm. Walley, Virginia Iron, Coal and Coke Co., Roanoke, Va. (50). **C**
Davison, Alvin, Ph. D., Lafayette College, Easton, Pa. (49).

Davison, John M., 340 Oxford St., Rochester, N. Y. (38). **C**

Daviss, Edward Paxton, M. D., 205–6 Binz Building, Houston, Texas, (51). **K**

Davy, Joseph Burtt, Asst. Botanist. Agric. Exper. Station, Berkeley, Cal. (51) **G**

Dawson, Percy Millard, M. D., Instructor in Physiology, Johns Hopkins Medical School, Baltimore, Md. (50). **K**

*Day, Fisk H., M. D., 309 Sycamore St., Lansing, Mich. (20). 1874. **E F H**

*DAY, WILLIAM SCOFIELD, Ph. D., Tutor in Physics, Columbia University, New York, N. Y. (50). 1901. **B**

Dean, Seth, C. E., Surveyor of Mills County, Glenwood, Iowa. (34). **D**

Dean, Wm. H., 167 West River St., Wilkes-Barre, Pa. (50). **C**

Deans, John Sterling, Chief Engineer, Phoenix Bridge Co. Phoenixville, Pa. (51). **D**

de Arozarena, Rafael M., Consulting Engineer, 2da Calle de las Estaciones, Esquina de Encino, City of Mexico, Mexico. (51). **D**

de Benneville, James S., University Club, 1510 Walnut St., Philadelphia, Pa. (46). **C**

de Coppet, Henry, 22 West 17th St., New York, N. Y. (49).

Deens, Miss Anna M., 216 North Ave., W., Allegheny, Pa. (50). **F G**

de Forest, Robert W., 30 Broad St., New York, N. Y. (49).

de Funiak, Frederick, Consulting Engineer, 204 E. Chestnut St., Louisville, Ky. (51). **D**

De Garmo, William Burton, M. D., Professor of Surgery, N. Y. Post Graduate Medical School and Hospital, 56 W. 36th St., New York, N. Y. (51). **K**

*Deghuée, Joseph A., Ph. D., 247 Harrison St., Brooklyn, N. Y. (40). 1900. **C**

*Delabarre, E. B., Ph. D., Professor of Psychology, Brown University, Providence, R. I. (49). 1901. **H I**

Delafield, Maturin L., Jr., Fieldston, Riverdale, New York, N. Y. (43). **G**

Delafond, E., Ingenieur Chimiste, P. O. Box 252, San Juan, Porto Rico. (50). **C**

DE LANDERO, CARLOS F., Asst. Director Pachuca and Real del Monte Mining Co., Pachuca, Mexico. (36). **B C**

Delano, Frederic A., Supt. of Motive Power, C. B. and Q. Railroad, 209 Adams St., Chicago, Ill. (50). **D**

Delany, Patrick Bernard, E. E., Inventor, South Orange, N. J. (50). **D**

Dellenbaugh, Frederick S., Century Club, 7 West 43d St., New York, N. Y. (51). **H**

Dempster, Alexander, Stanton and Euclid Aves., Pittsburg, Pa. (50). **D**

*Dennis, David Worth, Professor of Biology, Earlham College, Richmond, Ind. (50). 1901. **F**

*Dennis, Louis Monroe, Cornell University, Ithaca, N. Y. (43). 1895. **C**

*Denton, Prof. James E., Stevens Institute, Hoboken, N. J. (36). 1888. **A B D**

de Raasloff, Harold, Civil Engineer, 18 Burling Slip, New York, N. Y. (51). **D**

Derby, George McClellan, Major, Corps of Engineers, U. S. A., 3232 Prytania St., New Orleans, La. (50). **D**

*Derby, Orville A., Commissao Geologica, Sao Paulo, Brazil, South America. (39). 1890. **E**

*de Schweinitz, E. A., M. D., U. S. Dept. Agriculture, Washington, D. C. (36). 1889. **C**

Detmers, Fredericka, 1315 Neil Ave., Columbus, Ohio. (48). **G**

Devereux, W. B., 99 John St., New York, N. Y. (50).

*Dewey, Lyster H., U. S. Dept. Agriculture, Washington, D. C. (40). 1899. **F G**

*Dexter, Franklin, M. D., Associate Professor of Anatomy, Harvard Medical School, Boston, Mass. (50). 1901. **K**

Dickerson, E. N., 141 Broadway, New York, N. Y. (49).

Dickinson, Gordon K., M. D., 278 Montgomery St., Jersey City, N. J. (51). **K**

Diemer, Hugo, Associate Professor of Mechanical Engineering, Univ. of Kansas, Lawrence, Kans. (49).

*Dimmock, George, Box 1597, Springfield, Mass. (22). 1874. **F**

Dimock, Mrs. Henry F., 25 East 60th St., New York, N. Y. (50).

Dimon, Miss Abigail Camp, 367 Genesee St., Utica, N. Y. (50). **F K**

Dinkey, Alva C., General Supt. Homestead Steel Works, Munhall, Pa. (50). **D**

Dinsmore, Prof. Thos. H., Jr., 1012 E. Adams St., Syracuse, N. Y. (29). **B C**

Disbrow, William S., M. D., 151 Orchard St., Newark, N. J. (51). **K**

*Dixon, Roland B., Peabody Museum, Cambridge, Mass. (46). 1901. **H**

Dixon, Samuel Gibson, M. D., Acad. Nat. Sciences, 1900 Race St., Philadelphia, Pa. (50). **F K**

Dock, George, M. D., 1014 Cornwell Place, Ann Arbor, Mich. (51). **K**

*Dodge, Charles Richards, U. S. Dept. of Agriculture, Washington, D. C. (22). 1874.

*Dodge, Charles Wright, Univ. of Rochester, Rochester, N. Y. (39). 1898. **F**

Dodge, D. Stuart, 225 Madison Ave., New York, N. Y. (49).

Dodge, Philip T., Tribune Building, New York, N. Y. (44). **B D**

*Dodge, Richard E., Teachers' College, Columbia Univ., New York, N. Y. (49). 1901. **E I**

Dodman, Alfred C., Jr., 235 W. 108th St., New York, N. Y. (50).

Doherty, Henry L., 40 Wall St., New York, N. Y. (48). **B C D**

Doherty, Manning William, Associate Professor of Biology, Ontario Agricultural College, Guelph, Canada. (50). **F G**

*Dolbear, Prof. A. Emerson, Tufts College, Mass. (20). 1880. **B**

Dole, Rev. Charles Fletcher, Jamaica Plain, Mass. (50). **I**

Domenech, Manuel V., Civil Engineer and Architect, Lock Box 220, Ponce, Porto Rico. (50). **D I**

Donovan, Cornelius, Assistant Engineer, U. S. Engineer Office, Custom House, New Orleans, La. (51). **D**

*Doolittle, Prof. C. L., Upper Darby, Pa. (25). 1885. **A**

*Dorsey, George A., Ph. D., Field Columbian Museum, Chicago, Ill. (39). 1892. **H**

Dorsey, Herbert Grove, Granville, Ohio. (51). **B**

*Dorsey, N. Ernest, Ph. D., Annapolis Junction, Md. (46). 1898. **B**

Doty, Paul, 230 Woodward Ave., Detroit, Mich. (43). **D**

Doubt, Thomas E., Professor of Physics and Electrical Engineering, Univ. of Washington, Seattle, Wash. (48). **B**

Doughty, Mrs. Alla, Milford, Pa. (49).

Doughty, John W., 165 Johnston St., Newburgh, N. Y. (19). **E**

Douglas, Mrs. George William, Tuxedo Park, N. Y. (49).

Douglas, James, 99 John St., New York, N. Y. (49).

Douglas, Orlando B., 20 Pleasant St., Concord, N. H. (49).

*Douglass, Andrew E., Amer. Mus. of Nat. History, Central Park, New York, N. Y. (31). 1885. **H**

Dow, Herbert H., Midland, Mich. (47). **C**

Dowell, Philip, Ph. D., U. S. National Museum, Washington, D.C. (50). **F**

Downing, Elliott Rowland, Ph. D., Professor of Biology, Northern State Normal School, Marquette, Mich. (51). **F**

Downs, Edgar Selah, 1420 Pine St., Philadelphia, Pa. (50). **B**

*DRAPER, DANIEL, Ph. D., N. Y. Meteorological Observatory, Central Park, 64th St., Fifth Ave., New York, N. Y. (29). 1881. **A B D F**

Draper, Mrs. Henry, 271 Madison Ave., New York, N. Y. (49).

Drayer, H. C., Superintendent of Schools, Manteno, Ill. (51).

Drescher, Willibald A. E., P. O. Drawer 1033, Rochester, N. Y. (41). **F**

*DROPPERS, GARRETT, President of the State University, Vermillion, S. Dak. (50). 1901. **I**

*Drown, Prof. Thos. M., Lehigh University, South Bethlehem, Pa. (29). 1881. **C**

Drummond, Isaac Wyman, Ph. D., 436 W. 22d St., New York, N. Y. (36).

Dryer, Charles Redway, Professor of Geography, Indiana State Normal School, Terre Haute, Ind. (50). **E**

Duane, Russell, 911 Pine St., Philadelphia, Pa. (50). **I**

*Duane, William, Ph. D., Professor of Physics, State University, Boulder, Colo. (50). 1901. **B**

*Du Bois, Prof. Aug. J., New Haven, Conn. (30). 1882. **A B D**

De Bois, Howard Weidner, 4526 Regent St., Philadelphia, Pa. (47). **A**

*Du Bois, Patterson, 401 So. 40th St., Philadelphia, Pa. (33). 1887. **C H I**

DuBois, Wm. E. B., Professor of Economics and History, Atlanta University, Atlanta, Ga. (50). **I**

Du Bose, F. G., M. D., 915 Alabama St., Selma, Ala. (51). **K**

Dudgeon, H. R., M. D., Demonstrator of Surgery, School of Medicine, University of Texas, Galveston, Texas. (50). **F K**

*Dudley, Charles B., Drawer 334, Altoona, Pa. (23). 1882. **B C D**

Dudley, S. W., 15 Austin St., Westville, Conn. (50). **A D**

*Dudley, Wm. L., Vanderbilt University, Nashville, Tenn. (28). 1881. **C**

*Dudley, Prof. Wm. R., Dept. of Systematic Botany, Stanford University, Cal. (29). 1883. **G**

*Duggar, Benjamin Minge, U. S. Dept. Agriculture, Washington, D. C. (45). 1900. **G**

Duke, Frank Williamson, Professor of Mathematics, Hollins Institute, Hollins, Va. (50). **A**

Dulles, Charles W., M. D., 4101 Walnut St., Philadelphia, Pa. (51). **K**

Dumaresq, Philip K., Sears Bldg., Boston, Mass. (50).

*Dumble, E. T., Consulting Geologist, Southern Pacific Co., 1708 Prairie Ave., Houston, Tex. (37). 1891. **E**

Duncan, Fred. N., Chemist, Georgetown, Texas. (50). **C**

Duncan, George Martin, Professor of Philosophy, Yale University, New Haven, Conn. (50). **H**

Duncanson, Henry Bruce, Professor of Biology, State Normal School, Peru, Neb. (50). **F**

Duncklee, John B., Civil Engineer, 35 Fairview Ave., South Orange, N. J. (51). **D**

*Dunham, Edward K., 338 E. 26th St., New York, N. Y. (30). 1890.

Dunham, Henry Bristol, M. D., State Sanatorium, Rutland, Mass. (51). **K**

Dunlevy, Robert Baldwin, Prof. Kansas State Normal College, Winfield, Kansas. (50). **C E**

Dunn, Gano Sillick, Electrical Engineer, Crocker-Wheeler Company, Ampere, N. J. (50). **D**

Dunn, Miss Louise Brisbin, Barnard College, Columbia University, New York, N. Y. (47). **G**

Dunning, Lehman H., M. D., 224 N. Meridian St., Indianapolis, Ind. (51). **K**

*Dunnington, Prof. F. P., University Station, Charlottesville, Va. (26). 1880. **C**

*Dunstan, A. St. C., Professor of Electrical Engineering, Polytechnic Institute, Auburn, Ala. (50). 1901. **B D**

*DuPont, Francis G., Wilmington, Del. (33). 1896. **A B D**

*Durand, Elias J., D. S., 402 Eddy St., Ithaca, N. Y. (41). 1899. **G**

Durand, John S., 146 Broadway, New York, N. Y. (49).

*Durand, W. F., Ph. D., Cornell University, Ithaca, N. Y. (37). 1890. **B**

*Durfee, William P., Ph. D., 639 Main St., Geneva, N. Y. (46). 1899. **A**

Dutton, Charles Frederic, Jr., 626 Franklin Ave., Cleveland, Ohio. (47).

Duval, Edmund P. R., 2006 University Ave., Austin, Texas. (50).

Duvel, Joseph W. T., Botanical Lab., Univ. of Michigan, Ann Arbor, Mich. (48). **G**

Dwight, Dr. Jonathan, Jr., 2 E. 34th St., New York, N. Y. (49).

*Dwight, Thomas, M. D., Harvard Medical School, Boston, Mass. (47). 1898. **H K**

*Dwight, Prof. William B., Vassar College, Poughkeepsie, N. Y. (30). 1882. **E F**

*Dyar, Harrison G., Ph. D., U. S. National Museum, Washington, D. C. (43). 1898.

Dyche, Lewis Lindsay, Professor of Systematic Zoology and Taxidermist, University of Kansas, Lawrence, Kans. (51). **F**

Dysterud, E., Electrical Engineer, Monterey, Mexico. (50). **D**

Eagleson, James B., M. D., 512 Burke Bldg., Seattle, Wash. (51). **K**

*Earle, F. S., N. Y. Botanical Garden, Bronx Park, New York. (39). 1896. **G**

*Eastman, Charles Rochester, Museum Comp. Zoology, Cambridge, Mass. (41). 1896. **E F**

*Eastman, Prof. J. R., Andover, N. H. (26). 1879. **A**

*Eastwood, Miss Alice, Curator of Herbarium, California Academy of Sciences, San Francisco, Cal. (50). 1901. **G**

Eccles, David Charles, Chemist, Agricultural College, Pullman, Wash. (50). **C**

*Eccles, Robert G., M. D., 191 Dean St., Brooklyn, N. Y. (31). 1894. **C F**

Eckel, Edwin C., C. E., Assistant in Geology, N. Y. State Museum, Albany, N. Y. (51). **E**

Eckles, C. H., Columbia, Mo. (50). **F**

*Eddy, Prof. H. T., Univ. of Minnesota, Minneapolis, Minn. (24). 1875. **A B D**

Edes, Robert Thaxter, M. D., 15 Greenough Ave., Jamaica Plain, Mass. (50). **F H K**

Edgar, Clinton G., 72 Jefferson Ave., Detroit, Mich. (46).

Edmands, Isaac Russell, Supt. Union Carbide Co., Sault Ste. Marie, Mich. (50). **C D**

Edmonds, Richard H., President and Editor, "Manufacturers' Record," Baltimore, Md. (50). **D**

*Edwards, Prof. Charles Lincoln, Trinity College, Hartford, Conn. (49). 1900. **F**

Edwards, Prof. John W., Iowa Wesleyan University, Mt. Pleasant Iowa. (48).

Ehrenfeld, Frederick, Ph. D., Instructor in Geology, University of Pennsylvania, Philadelphia, Pa. (50). **E**

Ehrhorn, Edward Macfarlane, County Entomologist, Santa Clara Co., Mountain View, Cal. (50). **F**

*Eichelberger, William Snyder, Ph. D., Nautical Almanac Office, U. S. Naval Observatory, Washington, D. C. (41). 1896. **A**

Eisland, John, Ph. D., Professor of Mathematics, Thiel College, Greenville, Pa. (50). **A**

*Eigenmann, Carl H., Ph. D., Indiana University, Bloomington, Ind. (48). 1899. **F**

Eilers, Anton F., Mining Engineer and Metallurgist, 751 St. Marks Ave., Brooklyn, N. Y. (50). **D E**

*Eimbeck, William, U. S. C. and G. Survey, Washington, D. C. (17). 1874. **A B D**

Eimer, August, 220 East 19th St., New York, N. Y. (50).

Elder, E. Waite, Instructor in Physics, High School, Denver, Colo. (50). **B**

Elftman, Arthur Hugo, Ph. D., Mining Engineer, 706 Globe Building, Minneapolis, Minn. (50). **E**

*Elkin, William L., Yale University Observatory, New Haven, Conn. (33). 1885. **A**

Elliot, George T., M. D., 36 East 35th St., New York, N. Y. (50). **F K**

Ellis, Frederick W., M. D., Monson, Mass. (47). **B H**

Ellis, H. Bert, M. D., 243–246 Bradbury Block, Los Angeles, Cal. (50). **K**

Ellis, Robert W., Hurley, S. D. (50). **E**

*Elrod, Morton John, Professor of Biology, University of Montana, Missoula, Mont. (50). 1901. **F**

Ely, Sumner B., Chief Engineer American Sheet Steel Co., Vandergrift Building, Pittsburg, Pa. (50). **D**

*Ely, Theo. N., Chief of Motive Power, Pennsylvania R.R., Broad St. Station, Philadelphia, Pa. (29). 1886. **D**

*Emerson, Prof. Benjamin K., Box 203, Amherst, Mass. (19). 1877. **E F**

*EMERSON, C. F., Box 499, Hanover, N. H. (22). 1874. **A B**

*Emery, Albert H., Stamford, Conn. (29). 1884. **B D**

Emery, Albert Hamilton, Jr., 312 Main St., Stamford, Conn. (47). **D**

Emmerton, Frederic Augustus, 9 Bratenahl Bldg., Cleveland, Ohio. (50). **I**

Emmons, Arthur B., Newport, R. I. (50). **E**

*EMMONS, S. F., U. S. Geol. Survey, Washington, D. C. (26). 1879. **E**

Enders, Howard Edwin, Professor of Biology, Lebanon Valley College, Annville, Pa. (50). **F G**

*Engelman, George J., M. D., 336 Beacon St., Boston, Mass. (25). 1875. **F H**

Engle, Wilber Dewight, Professor of Chemistry, University of Denver, University Park, Colo. (50). **C**

*Engler, Edmund Arthur, President Worcester Polytechnic Institute, Worcester, Mass. (50). 1901. **A**

English, William Thompson, M. D., Professor of Physical Diagnosis, Western University of Pennsylvania, Pittsburg, Pa. (50). **K**

ENO, A. F., 32 Fifth Avenue, New York, N. Y. (50).

Eno, John Chester, Waldorf-Astoria Hotel, New York, N. Y. (49).

Epper, Rev. Frowin, O. S. B., Mt. Angel, Oregon. (50). **F**

Esmond, Darwin W., Newburgh, N. Y. (50). **A I**

ESTES, DANA, Brookline, Mass. (29). **H I**

Evans, Alexander W., M. D., 12 High St., New Haven, Conn. (45). **G**

Evans, Henry Brown, 3009 Cambridge Place, Washington, D. C. (48). **A**

Evans, Samuel G., 211 Main St., Evansville, Ind. (39). **F**

Evans-Carrington, Rev. Edward, 227 E. Cucharras St., Colorado Springs, Colo. (51). **I**

Evers, Edward, M. D., 1861 N. Market St., St. Louis, Mo. (28). **F H**

Everts, Orpheus, M. D., Medical Superintendent, The Cincinnati Sanitarium, Sta. K, Cincinnati, Ohio. (51). **K**

*Ewell, Ervin E., 1804 S St., Washington, D. C. (40). 1896. **C**

*Eyerman, John, "Oakhurst," Easton, Pa. (33). 1889. **C E**

Faile, Thomas H., Murray Hill Hotel, New York, N. Y. (50).

*Fairbanks, Henry, Ph. D., St. Johnsbury, Vt. (14). 1874. **A B D**

Fairchild, B. T., P. O. Box 1120, New York, N. Y. (36).

*Fairchild, David Grandison, U. S. Dept. Agriculture, Washington, D. C. (47). 1898. **G**

*Fairchild, Prof. H. L., Univ. of Rochester, Rochester, N. Y. (28). 1883. **E F**

Falconer, William, Schenley Park, Pittsburg, Pa. (29).

Falding, Frederic J., Consulting Chemical Engineer, 52 Broadway, New York, N. Y. (50). **C**

Falk, Gustav, 24 East 81st St., New York, N. Y. (50).

*Fanning, John T., Consulting Engineer, Kasota Block, Minneapolis, Minn. (29). 1885. **D**

*Fargis, Rev. Geo. A., S. J., Boston College, 761 Harrison Ave., Boston, Mass. (40). 1892.

Farley, Godfrey Pearson, C. E., General Manager, W. W. & F. R. R. Co., Wiscasset, Maine. (51). **D**

*Farlow, Dr. W. G., 24 Quincy St., Cambridge, Mass. (20). 1875. **G**

Farnsworth, Philo J., M. D., Clinton, Iowa. (50). **K**

Farquhar, Miss Helen, State Normal School, West Chester, Pa. (50). **A B**

*Farquhar, Henry. Census Office, Washington, D. C. (33). 1886. **A B G I**

Farr, Marcus S., Sc. D., Princeton Univ., Princeton, N. J. (49). **E**

Farrand, Livingtson, M. D., Columbia University, New York, N. Y. (50). **H**

Farwell, Elmer S., Steam Engineer, 507 W. 142d St., New York, N. Y. (51). **A D**

Farwell, Robert Benneson, C. E., 53 Monument Ave., Charlestown, Mass. (47). **D**

*Fassig, Oliver Lanard, Johns Hopkins University, Baltimore, Md. (46). 1899. **B**

Fast, Richard Ellsworth, Professor American History and Political Sciences, West Virginia University, Morgantown, W. Va. (50). **I**

Faught, John B., Professor of Mathematics, Northern State Normal School, Marquette, Mich. (50). **A**

Fawcett, Ezra, Mechanical and Electrical Engineer, 233 Ely St., Alliance, Ohio. (48). **B D**

Fay, L. G., Naval Office, 20 Exchange Place, New York, N. Y. (50).

Fellows, Charles S., 925 Guaranty Building, Minneapolis, Minn. (34) **F**

Felt, Charles Wilson, 185 Austin St., Worcester, Mass. (47). **I**

*Felt, Ephraim Porter, Ph. D., State Entomologist, Albany, N. Y. (44). 1899. **F**

Fenneman, Nevin M., Ph. D., Professor of Geology, University of Colorado, Boulder, Colo. (51). **E**

Fényes, Adalbert, M. D., P. O. Box W, Pasadena, Cal. (51). **F**

Ferguson, Alexander McGowen, Instructor in Botany, Univ. of Texas, Austin, Texas. (51). **G**

Fernald, F. A., Broadway and 117th St., New York, N. Y. (43). **C**

*Fernow, Bernhard E., Director N. Y. State College of Forestry, Cornell University, Ithaca, N. Y. (31). 1887. **G I**

Ferril, William C., Curator, State Historical and Natural History Society of Colorado, Denver, Colo. (50). **E F G H I**

Ferry, Dexter M., Jr., Seedsman, 1040 Woodward Ave., Detroit, Mich. (50). **G**

*Fessenden, Prof. Reginald A., U. S. Weather Bureau, Washington D. C. (47). 1899. **A B**

Fetterman, John Colvin, Castle Shannon, Pa. (51). **E F**

*Fewkes, Dr. J. Walter, Bureau of Amer. Ethnology, Washington, D. C. (48). 1900. **H**

Field, Archelaus G., M. D., LL. B., Summit Place, Des Moines, Iowa. (48).

Field, George Wilton, Mass. Inst. Tech., Boston, Mass. (47).

Field, W. L. W., Milton, Mass. (47). **F**

Finch, John Wellington, State Geologist, Victor, Colo. (50). **E**

Findlay, Merlin C., Professor of Biology, Park College, Parkville, Mo. (50). **F**

*Fink, Prof. Bruce, Upper Iowa Univ., Fayette, Iowa. (45). 1890. **G**

*Firmstone, F., Cranberry, N. C. (33). 1887. **D**

Fischel, Washington E., M. D., 2647 Washington, Ave., St. Louis, Mo. (50). **F K**

Fisher, Louis Albert, U. S. C. and G. Survey, Washington, D. C. (47). **A B C**

Fish, Charles Henry, M. E., General Manager, Cocheco Mf'g Co., Dover, N. H. (51). **D**

*Fish, Pierre A., D. V. S., Ithaca, N. Y. (49). 1901. **K**

Fish, Walter Clark, General Elec. Co., Lynn, Mass. (50). **D**

Fishburne, Edward Bell, Jr., President Hoge Memorial Military Academy, Blackstone, Va. (51). **D**

Fisher, George E., 37 and 39 Wall St., New York, N. Y. (37).

Fisher, George Egbert, University of Pennsylvania, Philadelphia, Pa. (51).

Fisher, Henry Wright, Electrical Engineer, S. U. Cable Co., Pittsburg, Pa. (51). **D**

*Fisher, Irving, Ph. D., 460 Prospect St., New Haven, Conn. (50). 1901. **A I**

Fisher, Robert Jones, 614 F St., N.W., Washington, D. C. (50). **D**

Fisher, Robert Welles, M. D., 159 E. 2d South St., Salt Lake City, Utah. (51). **K**

Fisher, S. Wilson, 1502 Pine St., Philadelphia, Pa. (51). **A**

Fisher, William Bowditch, General Manager, American Zinc, Lead and Smelting Co., Cartersville, Mo. (50). **C D E**

Fisk, Herbert F., Principal of the Academy, Northwestern University, Evanston, Ill. (50).

*Fiske, Prof. Thomas S., Columbia University, New York, N. Y. 1901. (50).

Fiske, Wilbur A., Professor of Science, Richmond High School, Richmond, Ind. (51). **B**

*Fitz, George W., M. D., 483 Beacon St., Boston, Mass. (47). 1898. **H**

Fitz Gerald, Francis A. J., P. O. Box 118, Niagara Falls, N. Y. (50). **C.**

Flanders, Charles S., Franklin, Mass. (42). **E**

*Flather, John J., Professor of Mechanical Engineering, University of Minnesota, Minneapolis, Minn. (44). 1896. **D**

Fleming, John A., 1109 13th St., N. W., Washington, D. C. (48).

Fleming, Miss Mary A., The Oxford, 432 Pearl St., Buffalo, N. Y. (47). **E G**

Flemming, Dudley D., Gas Engineer, 249 Washington St., Jersey City, N. J. (50). **C D**

*Fletcher, Miss Alice C., Peabody Museum, Cambridge, Mass. (29). 1883. **H**

FLETCHER, ANDREW, 339 West 77th St., New York, N. Y. (50).

*Fletcher, James, Ph. D., Dominion Entomologist, Experimental Farm, Ottawa, Can. (31). 1883. **F**

*Fletcher, Robert, M. D., Army Medical Museum, Washington, D. C. (29). 1881. **F H**

*Fletcher, Robert, Ph. D., Director of Thayer School of Civil Engineering, Hanover, N. H. (51). 1902. **D**

Flickinger, Junius R., Sc. D., Principal of Normal School, Pres., Pa. Educational Assn.. Normal School, Lock Haven, Pa. (51).

*Flint, Albert S., Washburn Observatory, Madison, Wis. (30). 1887. **A**

*Flint, Austin, M. D., LL.D., Professor of Physiology, Cornell University Medical College, New York, N. Y. (50). 1901. **F K**

*Flint, James M., Surgeon U. S. N., The Portland, Washington, D. C. (28). 1882. **F**

Focke, Theodore M., Case School of Applied Science, Cleveland, Ohio. (44). **A B**

*Foley, Prof. Arthur Lee, Indiana University, Bloomington, Ind. (46). 1900. **B**

Folkmar, Daniel, D. S. S., D. U. Paris, care. Mrs Geo. Cuddeback, 5 Glen Etta St., Janesville, Wis. (46). **H**

Folsom, David M., Stanford, University, Cal. (51). **E**

Foote, James S., M. D., Creighton Medical College, Omaha, Neb. (50). **F K**

Foote, Warren M., 311 N. 33d St., Philadelphia, Pa. (50). **C**

Forbes, Robert H., Professor of Chemistry, University of Arizona, Tucson, Arizona. (50). **C**

Forcee, Miss Margaret P., M. D., Arch near Ohio St., Allegheny, Pa. (51). **K**

Ford, James B., 4 East 43d St., New York, N. Y. (49).

Fort, I. A., U. P. Land Agent, North Platte, Neb. (51).

Foster, Macomb G., P. O. Box 1120, New York, N. Y. (49).

Foster, William, Newburgh, N. Y. (50). **I**

Fowler, Edwin H., U. S. C. and G. Survey, Washington, D. C. (47).

Fox, Charles James, M. D., Lock Box A, Willimantic, Conn. (51). **K**

*Fox, Oscar C., U. S. Patent Office, Washington, D. C. (36). 1891. **A B D**

Fox, William, Asst. Professor Physics, College of the City of New York, New York, N. Y. (50). **B D**

Fraenkel, Joseph, M. D., 46 East 75th St., New York, N. Y. (50). **K**

Francis, Charles Kenworthy, Ph. B., Adjunct Prof. of Chemistry, Ga. School of Technology, Atlanta, Ga. (50). **C**

Francisco, M. Judson, 49 Merchants' Row, Rutland, Vt. (50). **I**

*Frankforter, George B., University of Minnesota, Minneapolis, Minn. (43). 1901. **C**

Frankland, Frederick W., 346 Broadway, New York, N. Y. (50).

*Franklin, Mrs. C. Ladd, 516 Park Ave., Baltimore, Md. (47). 1899. **H**

*Franklin, Edward Curtis, Ph. D., Kansas State Univ., Lawrence, Kan. (47). 1900. **B G**

*Franklin, William S., Lehigh University, So. Bethlehem, Pa. (36). 1892. **B**

*FRAZER, DR. PERSIFOR, Drexel Building, Room 1042, Philadelphia, Pa. (24). 1879. **C E**

*Frazier, Prof. B. W., Lehigh University, So. Bethlehem, Pa. (24). 1882. **C E**

*Frear, William, State College, Pa. (33). 1886. **C**

Frederick, Charles Warnock, U. S. Naval Observatory, Washington, D. C. (50). **A B C**

Freeborn, George C., M. D., 215 West 70th St., New York, N. Y. (50). **K**

*Freedman, William Horatio, Professor of Electrical Engineering, University of Vermont, Burlington, Vt. (50). 1901. **B D**

Freeman, Charles, Ph. D., Director of Clark Chemical Laboratory, Westminster College, New Wilmington, Pa. (50). **C**

Freeman, Prof. T. J. A., St. John's College, Fordham, New York, N. Y. (33). **B C**

*Freer, Prof. Paul C., Ann Arbor, Mich. (39). 1891. **C**

Freley, Jasper Warren, Wells College, Aurora, N. Y. (45). **B E**

French, E. L., Crucible Steel Co. of America, Syracuse, N. Y. (51). **C**

*French, Prof. Thomas, Jr., Amherst, Mass., (30). 1883. **B**

Fretz, Augustus Henry, Doylestown, Pa. (50).
Fretz, John Edgar, M. D., 112 North 3d St., Easton, Pa. (46). **F G H**
Frick, Prof. John H., Central Wesleyan College, Warrenton, Mo. (27). **A B E F**
Friedenwald, Harry, M. D., Associate Prof. of Ophthalmology and Otology, College of Phys. and Surgs., 1029 Madison Ave., Baltimore, Md. (51). **K**
Friend, Samuel Henry, M. D., 141 Wisconsin St., Milwakuee, Wis. (51). **K**
*Fries, Dr. Harold H., 92 Reade St., New York, N. Y. (40). 1898. **C**
FRISBIE J. F., M. D., Box 455, Newton, Mass. (29). **E H**
*Frisby, Prof. Edgar, U. S. Naval Observatory, Washington, D. C. (28). 1880. **A**
*Frost, Edwin Brant, Yerkes Observatory, Williams Bay, Wis. (38). 1890. **A B**
Frost, George H., C. E., Editor of "Engineering News," 220 Broadway, New York, N. Y. (50). **B D**
Frost, Miss Lucy Ames, 35 Robinson St., Dorchester, Mass. (47). **B**
Frost, William Dodge, Instructor in Bacteriology, University of Wisconsin, Madison, Wis. (50). **F**
FROTHINGHAM, MRS. FREDERICK, 152 Pautucket St., Lowell, Mass. (31). **A F I**
Fuller, Arthur Levens, Brunner, Kans. (50). **C**
Fuller, Charles Gordon, M. D., Reliance Building, Chicago, Ill. (35). **F**
Fuller, George W., 100 William St., New York, N. Y. (50).
*Fuller, Prof. Homer T., President Drury College, Springfield, Mo. (35). 1891. **C E**
*Fuller, Melville W., LL.D., Chief Justice U. S. Supreme Court, 1800 Massachusetts Ave., Washington, D. C. (40). 1901. **I**
FULLER, MYRON L., Assistant Geologist, U. S. Geological Survey, Washington, D. C. (50). **E**
Fullmer, Edward Lawrence, Prof. of Natural Science, Dakota Univ., Mitchell, S. D. (50). **F**
*Fulton, Robert B., Chancellor Univ. of Mississippi, University, Miss. (21). 1887. **A B**
Fulton, Weston Miller, Instructor in Meteorology, University of Tennessee, Knoxville, Tenn. (50). **B**
Furlow, Floyd Charles, Professor of Experimental Engineering, Georgia School of Technology, Atlanta, Ga. (50). **D**
*Furness, Miss Caroline E., Vassar College Observatory, Poughkeepsie, N. Y. (47). 1899. **A**
Gable, George D., Ph. D., Parsons College, Fairfield, Iowa. (40). **A B**
*Gage, Prof. Simon Henry, Cornell University, Ithaca, N. Y. (28). 1881. **F**

*Gage, Mrs. Susanna Phelps, Ithaca, N. Y. (48). 1900. **F**

Gage-Day, Mary, M. D., 207 Wall St., Kingston-on-Hudson, N. Y. (51). **K**

Gager, C. Stuart, Professor of Biologic Science, New York State Normal College, Albany, N. Y. (50). **F G**

Gahagan, William L., M. D., 141 Broadway, New York, N. Y. (51). **K**

Gaither, George R., ex-Attorney General of Maryland, 1310 Continental Bldg., Baltimore, Md. (50). **I**

*Galbraith, Prof. John, School of Practical Science, Toronto, Can. (38). 1889. **D**

*Galloway, B. T., U. S. Dept. Agriculture, Washington, D. C. (37). 1890. **G**

*Galloway, Thomas Walton, Professor of Biology, Missouri Valley College, Marshall, Mo. (45). 1901. **F G**

*Ganong, Wm. F., Professor of Botany, Smith College, Northampton, Mass. (49). 1900. **G**

Gantt, Henry Lawrence, Consulting Enigneer, care American Locomotive Co., Schenectady, N. Y. (51). **D I**

Garcin, Ramon D., M. D., 2618 E. Broad St., Richmond, Va. (51). **K**

Gardiner, Charles Fox, M. D., 818 N. Cascade Ave., Colorado Springs, Colo. (51). **K**

Gardiner, Edward G., Ph. D., 131 Mt. Vernon St., Boston, Mass. (51).

Gardiner, Rev. Frederic, Jr., Yeates School, Lancaster, Pa. (47). **F H**

Gardner, Rev. Corliss B., Ripley, N. Y. (29). **A B I**

Gardner, Geo. Clinton, 416 Beach St., N., Richmond Hill, New York, N. Y. (50).

Garland, Jos. E., M. D., 17 Pleasant St., Gloucester, Mass. (51). **K**

Garnier, Madame Laure Russell, The Castle, Tarrytown, N. Y. (40).

Garrett, Albert O., Fort Scott, Kansas. (50). **G**

Garriott, Edward B., U. S. Weather Bureau, Washington, D. C. (49).

Garver, John A., 44 Wall St., New York, N. Y. (49).

Garvin, John B., Instructor in Chemistry, High School District No. 1. Denver, Colo. (50). **C**

Gates, Fanny Cook, Instructor in Physics, Woman's College, Baltimore, Md. (50). **A B**

Gault, Franklin B., 602 N. I St., Tacoma, Wash. (43).

Gause, Fred Taylor, Manager Standard Oil Co. of New York, T. and B. Dept. Yokohama, Japan. (40).

Gauss, Robert, Editor "Denver Republican," Denver, Colo. (50). **I**

Geisler, Joseph F., New York, Mercantile Exchange, New York, N. Y. (50).

*GENTH, FRED. A., 103 N. Front St., Philadelphia, Pa. (32). 1900. **C E**

*Genthe, Karl Wilhelm, Ph. D., Instructor in Zoology, Trinity College, Hartford, Conn. (50). 1901. **F**

*Germann, George B., 90 Norman Ave., Brooklyn, N. Y. (49). 1901. **A**

Getman, Frederick H., Johns Hopkins University, Baltimore, Md. (45). **B**

*Gibbs, Prof. J. Willard, New Haven, Conn. (33). 1885. **B**

*GIBBS, PROF. WOLCOTT, Newport, R. I. (1). 1896. **B C**

*Gies, William J., College of Physicians and Surgeons, 437 West 59th St., New York, N. Y. (49). 1901. **C**

Giffin, Frank Albee, 419 W. 118th St., New York, N. Y. (50). **A B**

Gifford, Harold, M. D., 405 Karbach Block, Omaha, Neb. (51). **K**

Gifford, John Clayton, Asst. Professor of Forestry, New York State College of Forestry, Ithaca, N. Y. (50). **G**

Gilbert, Charles B., Educator, 106 Brunswick St., Rochester, N. Y. (50). **I**

*GILBERT, G. K., U. S. Geol. Survey, Washington, D. C. (18). 1874. **E**

*Gill, Adam Capen, Cornell University, Ithaca, N. Y. (38). 1894. **E**

*Gill, Augustus Herman, Mass. Institute Technology, Boston, Mass. (44). 1896. **C**

*Gill, Theodore Nicholas, M. D., Cosmos Club, Washington, D. C. (17). 1874. **F**

*Gillette, Clarence P., Professor of Zoology, Agricultural College, Fort Collins, Colo. (50). 1901. **F**

Gilman, Charles Edward, Stanford University, Cal. (51). **E**

*Gilman, Daniel C., Johns Hopkins University, Baltimore, Md. (10). 1875. **E H**

Girty, George H., Ph. D., U. S. Geol. Survey, Washington, D. C. (48).

Glaser, C., Analytical and Consulting Chemist, 21 S. Gay St., Baltimore, Md. (49).

Gleason, H. Allan, Asst. in Botany, Univ. of Illinois, Champaign, Ill. (50). **G**

Gleason, W. Stanton, M. D., 143 Grand St., Newburgh, N. Y. (50). **F K**

Glenn, L. C., Ph. D., Professor of Geology, Vanderbilt University, Nashville, Tenn. (50). **E**

*Glenn, William, 1348 Block St., Baltimore, Md. (33). 1893. **C**

GLENNY, WILLIAM H., Buffalo, N. Y. (25).

Godfrey, Chas. C., M. D., 753 Lafayette St., Bridgeport, Conn. (51). **K**

Godkin, Mrs. E. L., 36 W. 10th St., New York, N. Y. (49).

*Goessmann, Prof. C. A., Mass. Agric. College, Amherst, Mass. (18). 1875. **C**

Gold, Rev. Dr. James Douglas, Covington, Ohio. (50). **I**

*Gold, Theodore S., West Cornwall, Conn. (4). 1887. **B C**

Golden, Harry E., Civil Engineer, Mann Building, Utica, N. Y. (51). **D**

*Golden, Miss Katherine E., Purdue University, Lafayette, Ind. (42). 1897. **G**

Goldsborough, John Byron, Croton-on-Hudson, N. Y. (51).

*Goldschmidt, S. A., Ph. D., 43 Sedgwick St., Brooklyn, N. Y. (24). 1880. **B C E**

*Goldsmith, Edw., 658 N. 10th St., Philadelphia, Pa. (29). 1892. **B C**

Goldthwait, James Walter, Assistant in Geology, Harvard University, Cambridge, Mass. (51). **E**

Goldthwaite, Miss Nellie Esther, Mount Holyoke College, So. Hadley, Mass. (47). **C**

Gomberg, Moses, Sc. D., 1101 E. University Ave., Ann Arbor, Mich. (51). **C**

*Gooch, Frank A., Yale University, New Naven, Conn. (25). 1880. **C**

*Goodale, Prof. George Lincoln, Botanic Gardens, Cambridge, Mass. (18). 1875. **G**

Goodale, Joseph Lincoln, M. D., 397 Beacon St., Boston, Mass. (50). **F K**

Goodnow, Henry R., 95 Riverside Drive, New York, N. Y. (32). **B**

*Goodspeed, Arthur Willis, Ph. D., Dept. Physics, University of Pennsylvania, Philadelphia, Pa. (47). 1898. **A B**

Goodwin, Elmer Forrest, Principal and Prof. Physics and Chemistry Concord Branch, West Virginia State Normal School, Athens, W. Va. (50). **B C**

*Goodwin, Harry M., Professor of Physical Chemistry, Mass. Institute Technology, Boston, Mass. (47). 1901. **B**

*Goodyear, William H., Museum of Brooklyn Institute of Arts and Sciences, Eastern Parkway, Broklyn, N.Y. (43). 1902. **H**

Gordon, Clarence McC., Ph. D., Centre College, Danville, Ky. (48). **A B C**

Gordon, Gustavus Ede, Scientific Director, Walker Gordon Laboratory Co., 1120 Conn. Ave., N. W., Washington, D. C. (51). **F**

Gordon, Reginald, 315 W. 71st St., New York, N. Y. (50).

Gordon, Robert H., Cumberland, Md., (48). **E F**

Gore, J. W., Professor Physics, Univ. of N. C., Chapel Hill, N. C. (51). **B**

*Goss, Prof. Wm. F. M., Lafayette, Ind. (39). 1896.

Gossard, Harry Arthur, Professor of Entomology, Florida Agricultural College, Lake City, Fla. (51). **F**

Goucher, John Franklin, President of The Woman's College, Baltimore, Md. (50).

*Gould, George Milbry, M. D., 1631 Locust St., Philadelphia, Pa. (51). 1902. **K**

Gouldy, Miss Jennie A., Newburgh, N. Y. (50). **I**
Grabill, H. P., 1004 Enas Ave., Des Moines, Iowa. (50). **C**
Graef, Edw. L., 58 Court St., Brooklyn, N. Y. (28). **F**
Graham, Douglas, M. D., 74 Boylston St., Boston, Mass. (51). **K**
Graham, James Chandler, Chemist, Phillips Academy, Andover, Mass. (50). **C**
Graham, Robert Dunn, 52 Broadway, New York, N. Y. (50).
Granbery, Julian Hastings, Engineer and Electrician, 561 Walnut St., Elizabeth, N. J. (50). **D**
Granger, Arthur O., Cartersville, Ga. (50). **A B**
*Grant, Ulysses Sherman, Ph. D., Professor of Geology, Northwestern University, Evanston, Ill. (50). 1902. **G**
Grant, Willis Howard, 744 South Ave., Wilkensburg, Pa. (51). **C G**
Granville, William Anthony, Ph. D., Instructor in Mathematics, Yale University, New Haven, Conn. (50). **A**
*Gratacap, L. P., 77th St. and 8th Ave., New York, N. Y. (27). 1884. **C E F**
*Gray, Prof. Thomas, Terre Haute, Ind. (38). 1889. **D**
Greef, Ernest F., 37 W. 88th St., New York, N. Y. (49).
*Green, Arthur L., Purdue University, Lafayette, Ind. (33). 1888. **C**
Green, Bernard Richardson, Civil Engineer, Supt. of Congressional Library Building, 1738 N St., N.W., Washington, D. C. (51). **B D**
Greene, Chas. Lyman, M. D., 150 Lowry Arcade, St. Paul, Minn. (51). **K**
*Greene, Charles Wilson, Ph. D., Professor of Physiology, State University of Missouri, Columbia, Mo. (50). 1901. **F K**
Green, Edgar Moore, M. D., Easton, Pa. (36). **C G H**
Greene, G. K., 127 W. Market St., New Albany, Ind. (38).
Green, Horace, care "Sunday Journal," 15 Spruce St., New York, N. Y. (50).
Green, Miss Isabella M., 111 Union Place, Akron, Ohio. (47).
Greene, J. Evarts, 98 Lincoln St., Worcester, Mass. (47). **I**
Greene, Jacob L., President Mut. Life Insurance Co., Hartford, Conn. (23).
Green, Milbrey, M. D., 567 Columbus Ave., Boston, Mass. (29).
Greenalch, Wallace, Deputy City Engineer, Albany, N. Y. (51). **D**
Greenleaf, Robert Willard, M. D., 561 Boylston St., Boston, Mass. (47).
*Greenman, Jesse M., 875 Doan St., Cleveland, Ohio. (47). 1899. **G**
Greenough, Charles Pelham, Attorney at law, 39 Court St., Boston, Mass. (50). **I**
Greenough, John, 31 W. 35th St., New York, N. Y. (49).
Gregg, William H., M. D., Port Chester, N. Y. (49).

Gregory, Miss Emily Ray, Ph. D., Professor of Biology, Wells College, Aurora, N. Y. (50). F

Gregory, Herbert E., Yale University, New Haven, Conn. (50). E

Griffin, Gen. Eugene, First Vice-President, General Electric Co., 44 Broad St., New York, N. Y. (50). D

Griffith, C. J., Instructor in Dairying, Agricultural College, Fort Collins, Colo. (50). F

Griffith, Daniel J., 21 W. 56th St., New York, N. Y. (49).

Griffith, Herbert Eugene, Professor of Chemistry, Knox College, Galesburg, Ill. (50). C

Griffith, John Howell, Professor of Mathematics and Civil Engineering, Clarkson School of Technology, Potsdam, N. Y. (50). D

Griffith, Miss Mary Dechert, 3914 Walnut St., Philadelphia, Pa. (47). B C

Griffith, W. W., Instructor in Physics, State University, Columbia, Mo. (50). B

Griffiths, David, Div. Agrostology, U. S. Dept. Agriculture, Washington D. C. (49). G

*Grimes, James Stanley, 1422 Wesley Ave., Evanston, Ill. (17). 1874. E H

Grimm, Carl Robert, Bridge and Structural Engineer Carnegie Hall, New York, N. Y. (51). D

Grimsley, George Perry, Professor of Geology, Washburn College, Topeka, Kansas. (51). E

*Grindley, Dr. Harry Sands, Associate Professor of Chemistry, University of Illinois, Urbana, Ill. (46). 1898. C

*Grinnell, George Bird, 346 Broadway, New. York, N. Y. (25). 1885. E F

Griswold, Clifford S., Head of Dept. of Physics, Groton School, Groton, Mass. (50). B

*Griswold, Leon Stacy, 238 Boston St., Dorchester, Mass. (38). 1893. E

Groat, Benjamin Feland, Assistant Professor of Mathematics and Mechanics, University of Minnesota, Minneapolis, Minn. (51). A

Grosskopf, Ernest C., M. D., Medical Superintendent Milwaukee County Hospital, Wauwatosa, Wis. (51). K

Grosvenor, Gilbert H., "National Geographic Magazine," Corcoran Bldg., Washington, D. C. (48). E I

*Grout, Abel J., Boys' High School, Brooklyn, N. Y. (47). 1899. G

Grover, Frederick Orville, Professor of Botany, Oberlin College, Oberlin, Ohio. (50) G

*Gruener, Hippolyte, Adelbert College, Cleveland, Ohio. (44). 1898.

*Gulliver, F. P., St. Marks School, Southboro, Mass. (40). 1900. E

Gummere, Henry Volkmar, Professor of Mathematics, Physics and Astronomy, Ursinius College, Collegeville, Pa. (51). **A B**

Guth, Morris S., M. D., Supt. State Hospital for the Insane, Warren, Pa. (51). **K**

*Guthe, Karl E., Ph. D., 904 S. State St., Ann Arbor, Mich. (45). 1897. **D**

Guthrie, William Alvis, M. D., Franklin, Ky. (51). **K**

Guthrie, William E., M. D., Bloomington, Ill. (51). **K**

Gutiérrez, Manuel R., Professor of Physics, Normal School, Calle de las Victimas num. 1, Jalapa, Vera Cruz, Mexico. (50). **B**

Hadley, Artemus N., Box 313, Indianapolis, Ind. (51). **D**

*Hagar, Stansbury, 179 Kingston Ave., Brooklyn, N. Y. (43). 1899.

*Hague, Arnold, U. S. Geol. Survey, Washington, D. C. (26). 1879. **E**

Hague, James D., 18 Wall St., New York, N. Y. (50).

Haight, Stephen S., C. E., 976 East 179th St., New York, N. Y. (31). **D**

*Haines, Reuben, Haines and Chew Sts., Germantown, Philadelphia, Pa. (27). 1889. **B C**

*Hale, Albert C., Ph. D., 352A Hancock St., Brooklyn, N. Y. (29). 1886. **B C**

Hale, George D., 1059 Lake Ave., Rochester, N. Y. (41).

*Hale, George E., Yerkes Observatory, Williams Bay, Wis. (37). 1891. **A B C**

*Hale, William H., Ph. D., 40 First Place, Brooklyn, N. Y. (19). 1874. **A B C E F H I**

*Hall, Asaph, U. S. N., South Norwalk, Conn. (25). 1877. **A**

*Hall, Asaph, Jr., University of Michigan, Ann Arbor, Mich. (38). 1890. **A**

Hall, Charles M., Vice-President Pittsburg Reduction Co., Niagara Falls, N. Y. (50). **C**

*Hall, C. W., Dean College of Engineering Met. and Mechan. Arts, University of Minnesota, Minneapolis, Minn. (28). 1883. **D E**

Hall, Edwin Bradford, Wellsville, N. Y. (50).

*Hall, Edwin H., 5 Avon St., Cambridge, Mass. (29). 1881. **B**

Hall, Fred. C., Jr., M. D., Cuba, Kansas, (51). **K**

Hall, James P., 6 Poplar St., Brooklyn, N. Y. (40). **A B**

Hall, Joseph Underwood, M. D., 216 Autumn St., San José, Cal. (51). **K**

Hall, Lyman, President of Georgia School of Technology, Atlanta, Ga. (50).

*Hall, Prof. Lyman B., Haverford College, Haverford, Pa. (31). 1884. **C**

Hall, Robert William, 2 Hillhouse Ave., New Haven, Conn. (50). **F**

Hall, William Bonnell, M. D., Professor of Materia Medica and Physiology, University of the South, Sewanee, Tenn. (51). **K**

Hall, William Shafer, Professor of Mining and Graphics, Lafayette College, Easton, Pa. (50). E

Hallack, H. Tuthill, M. D., Alcott, Colo. (51). K

Halley, Robert Burns, Professor of Physics and Chemistry, Sam Houston Normal Institute, Huntsville, Texas. (50). B C

*Hallock, Albert P., Ph. D., 440 First Ave., New York, N. Y. (31). 1896. C

Hallock, Frank Kirkwood, M. D., Cromwell, Conn. (50). K

*Hallock, Dr. William, Columbia University, New York, N. Y. (40). 1893. B E

*Hallowell, Prof. Susan M., Wellesley College, Wellesley, Mass. (33). 1890. G

*Halsted, Byron D., Rutgers College, New Brunswick, N. J. (29). 1883. G

*Halsted, George Bruce, M. D., 2407 Guadalupe St., Austin, Texas. (43). 1896.

Halsted, William Stewart, 1201 Eutaw Place, Baltimore, Md. (50).

Ham, Judson B., Teacher Natural Science, Vt. State Normal School, Johnson, Vermont. (50). F G

*Hamaker, John Irvin, Professor of Geology and Biology, Trinity College, Durham, N. C. (50). 1901. E F

*Hambach, Dr. G., 1319 Lami St., St. Louis, Mo. (26). 1891. E F

Hammatt, Clarence Sherman, Electrical and Mechanical Engineer, Jacksonville, Fla. (50). D

Hammel, Wm. C. A., Department of Physics, State Normal School, Baltimore, Md. (50). B F

Hammond, Mrs. Eliza F., 645 Jefferson Ave., Detroit, Mich. (46).

Hammond, George W., Hotel Hamilton, 260 Clarendon St., Boston, Mass. (47).

*Hammond, John Hays, Mining Engineer, Denver, Colo. (50). 1901. D E

Hammond, Mrs. John Hays, Denver, Colo. (50). H

*HANAMAN, C. E., Troy, N. Y. (19). 1883. F

Hance, Anthony M., 2024 DeLancey Place, Philadelphia, Pa. (51). C

Hancock, James Cole, M. D., 43 Cambridge Place, Brooklyn, N. Y. (51). K

Hard, Jas. M. B., Cordobanes 16, City of Mexico, Mexico. (50). C

*Harding, Everhart Percy, Instructor in Chemistry, University of Minnesota, Minneapolis, Minn. (50). 1901. C

Harding, Harry A., State Experiment Station, Geneva, N. Y. (48). G

Hardy, Edward R., 31 Allen St., Boston, Mass. (49). I

*Hargitt, Prof. Charles W., Syracuse University, Syracuse, N. Y. (38). 1891. F

*HARKNESS, WILLIAM, U. S. Naval Observatory, Washington, D. C. (26). 1878. A B C D

Harmon, Miss A. Maria, 171 McLaren St., Ottawa, Can. (31). F H

Harmon, Mrs. Israel, Springfield, Mass. (43).

Harnly, Henry Jacob, Ph. D., Professor of Biology, McPherson College, McPherson, Kan. (50). F G

*Harper, Charles A., Ph. D., 2139 Gilbert Ave., Cincinnati, Ohio. (40). 1899. C

*Harper, Henry Winston, M. D., The University of Texas, Austin, Texas. (45). 1899. C

Harper, R. H., M. D., Afton, Indian Ter. (51). F K

Harrah, C. J., P. O. Box 1606, Philadelphia, Pa. (48). H

*Harris, Abram Winegardner, Sc. D., Port Deposit, Md. (40). 1895. C

Harris, Mrs. Carolyn W., 125 St. Marks Ave., Brooklyn, N. Y. (50). G

*Harris, Prof. E. P., Amherst College, Amherst, Mass. (44). 1896.

Harris, Frederick S., Monticello, Kansas. (50). E

HARRIS, J. CAMPBELL, 119 So. 16th St., Philadelphia, Pa. (51).

*Harris, Rollin Arthur, U. S. C. and G. Survey, Washington, D. C. (47). 1899. A

Harris, Robert Wayne, M. D., 621 Vincennes St., New Albany, Ind. (51). K

*Harris, Uriah R., Commander, U. S. N., Room 225, Custom House, St. Louis, Mo. (34). 1886. A

Harrison, Judge Lynde, 52 Hillhouse Ave., New Haven, Conn. (50). I

*Harrison, Robert Henry, M. D., Columbus, Texas. (50). F K

Hart, Charles A., Assistant to State Entomologist, Univ. of Illinois, Urbana, Ill. (51). F

*Hart, Edw., Ph. D., Lafayette College, Easton, Pa. (33). 1885. C

Hart, James Norris, Professor of Mathematics and Astronomy, Univ. of Maine, Orono, Maine. (51). A

Hart, Miss Mary Elizabeth, Prospect Hill, Greenfield, Mass. (51). G

Hart, Rev. Prof. Samuel, Berkeley Divinity School, Middletown, Conn. (22). A

Hartley, Chas. P., Assistant in Plant Breeding, Bureau of Plant Industry, Dept. Agriculture, Washington, D. C. (51). G

Hartley, Frank, Principal of Allegheny County Academy, Cumberland, Md. (51). E G

Hartness, James, President of Jones and Lamson Machine Co., Springfield, Vt. (51). D

Hartz, J. D. Aug., College Point, N. Y. (43).

Hartzell, Prof. J. Culver, Illinois Wesleyan Univ., Bloomington, Ill. (49). E

Harvey, Wm. Stocker, 119 So. 4th St., Philadelphia, Pa. (47).

Hasie, Montague S., C. E., Manager of American Bridge Co., of New York, Dallas, Texas. (51). **D**

*Haskell, Eugene E., Campeau Building, Detroit, Mich. (39). 1896. **A B D**

Hasslacher, Jacob, 100 William St., New York, N. Y. (50).

*Hastings, C. S., Sheffield Scientific School, Yale University, New Haven, Conn. (25). 1878. **B**

Hastings, Edwin George, R. R. No. 2, Ashtabula, Ohio. (50). **F**

Hatcher, John Bell, Carnegie Museum, Pittsburg, Pa. (50). **E F**

Haupt, Herman, C. E., The Concord, Washington, D. C. (51). **D**

Haupt, Gen. Lewis Muhlenberg, C. E., Consulting Engineer, 107 North 35th St., Philadelphia, Pa. (51). **D**

Havemeyer, W. F., 32 Nassau St., New York, N. Y. (50).

Hawkins, J. Dawson, Colorado Springs, Colo. (50). **C D**

*Hay, Prof. Oliver Perry, Amer. Mus. Nat. History, Central Park, New York, N. Y. (49). 1901. **F**

Hay, Prof. William P., 1316 Wallach Place, N.W., Washington, D. C. (49).

Hayes, George Washington, C. E., Lebanon, Pa. (51). **C D**

Hayes, Joel Addison, Banker, Colorado Springs, Colo. (51).

Hayes, Noah, M. D., Seneca, Nemaha Co., Kansas. (51). **K**

*Hayford, John F., C. E., U. S. C. and G. Survey, Washington, D. C. (46). 1898. **A B D**

Haynes, Prof. Arthur E., College of Engineering, University of Minnesota, Minneapolis, Minn. (45).

*Haynes, Prof. Henry W., 239 Beacon St., Boston, Mass. (28). 1884. **H**

Haynes, Miss Julia Anna, Emma Willard School, Troy, N. Y. (47). **F G**

Hays, B. Frank, Bensonhurst, N. Y. (49).

Hays, Charles I., care North Side High School, Denver, Colo. (50). **C G**

Hays, C. Willard, U. S. Geological Survey, Washington, D. C. (51). **E**

*Hays, Willet M., Professor of Agriculture, University of Minnesota, St. Anthony Park, Minn. (45). 1901. **G I**

Haywood, Prof. John, Otterbein University, Westerville, Ohio. (30). **A B**

Hazard, Daniel L., U. S. C. and G. Survey, Washington, D. C. (48).

Hazard, R. G., Peace Dale, R. I. (50).

Hazen, Tracy Elliott, Director Fairbanks Museum, Saint Johnsbury, Vermont. (50). **G**

Head, W. R., 5467 Jefferson Ave., Hyde Park, Chicago, Ill. (38). **F**

Heald, Fred. DeForest, Ph. D., Professor of Biology, Parsons College, Fairfield, Iowa. (50). **F**

Heath, Harry E., Chief Enigneer, The Eddy Electric Mfg. Co., Windsor, Conn. (50). **D**

Hebden, Edwin, Principal of Group A, Public Schools, 730 Colorado Ave., Baltimore, Md. (50). **E**

Heck, Chas. McGee, Raleigh, N. C. (51). **B**

Hedgcock, George Grant, University of Nebraska, Lincoln, Neb. (50). **G**

Hedge, Frederic H., Public Library, Lawrence, Mass. (28). **F H**

*Hedrick, Henry B., Nautical Almanac Office, U. S. Naval Observatory, Washington, D. C. (40). 1896. **A**

Heisler, Chas. L., M. E., Mgr. and Engineer, Heisler Pumping Engine Co., 909 W. 8th St., Erie, Pa. (51). **D**

Heller, Napoleon B., Professor of Mathematics and Astronomy, Fort Worth University, Fort Worth, Texas. (50). **A**

Hellick, Chauncey Graham, C. E., Ph. D., 203 Washington St., Chicago, Ill. (50). **D**

Hemmeter, John C., M. D., Prof. in Medical Department Univ. of Maryland, 1734 Linden Ave., Baltimore, Md. (51). **K**

Henderson, Joseph J., 689 10th St., Brooklyn, N. Y. (51).

Henderson, Junius, County Judge, 1933 13th St., Boulder, Colo. (50).

*Henderson, William Edward, Ph. D., Ohio State University, Columbus, Ohio. (50). 1901. **C**

Hendricks, Henry H., 49 Cliff St., New York, N. Y. (30).

Hennen, Ray Vernon, C. E., care Carter Oil Co., Sistersville, W. Va. (50). **D**

Henrich, Carl, Mining Engineer, Union Copper Mining Co., Gold Hill, N. C. (50). **A E I**

*Henry, Alfred J., U. S. Weather Bureau, Washington, D. C. (49). 1901. **B**

Henry, Charles C., M. D., 56 Clark St., Brooklyn, N. Y. (43).

Hensel, Samuel Theodore, 801 E. Colfax Ave., Denver, Colo. (50). **C G**

Henzey, Sam'l Alexander, Pres. of Raleigh and Western Railway Co., 52 Broadway, New York, N. Y. (51).

Herbert, Arthur P., Engineer and Supt. Colima Division, Compania Constructora Nacional Mexicana, Colima, Colima, Mex. (51). **D**

Hering, Daniel Webster, Professor of Physics, New York University, University Heights, New York, N. Y. (50). **B D**

*Hering, Rudolph, 170 Broadway, New York, N. Y. (33). 1885. **D E I**

Herndon, John Henry, Tyler, Tex. (51). **C E**

Herr, Hiero B., Civil and Mining Engineer, 1246 Marquette Bldg., Chicago, Ill. (50). **E**

*Herrick, C. Judson, Dennison University, Granville, Ohio. (49). 1901. **F**

Herrick, Glenn W., Professor of Biology, A. and M. College, Agricultural College, Miss. (50). **F**

HERRMAN, MRS. ESTHER, 59 West 56th St., New York, N. Y.

Herrmann, Richard, Sec'y Iowa Institute of Science and Arts, Dubuque, Iowa. (50). **C E**

Herron, John Brown, S. Linden Ave., E. E., Pittsburg, Pa. (51). **I**

Hersom, Jane Loid, M. D., 106 Pine St., Portland, Me. (51). **K**

Herter, Christian A., M. D., 819 Madison Ave., New York, N. Y. (50). **K**

Herthel, Adolph, 1739 Waverly Place, St. Louis, Mo. (50). **I**

*Herty, Charles Holmes, Ph. D., Ocilla, Ga. (42). 1895. **C**

*Hervey, Rev. A. B., Bath, Me. (22). 1879. **F**

Herzog, Felix Benedict, Ph. D., President Herzog Teleseme Co., 51 West 24th St., New York, N. Y. (50). **D**

Hesse, Conrad E., U. S. Weather Bureau, Washington, D. C. (50). **A**

Heston, John W., President South Dakota Agricultural College, Brookings, S. D. (50). **I**

Hewett, Edgar L., President New Mexico Normal University, East Las Vegas, N. M. (50). **H**

Hewitt, Hon. Abram S., 9 Lexington Ave., New York, N. Y. (49).

Hewitt, Charles N., M. D., LL.D., Secretary State Board of Health, Red Wing, Minn. (50). **K**

HEXAMER, C. JOHN, C. E., 419 Walnut St., Philadelphia, Pa. (33). **B C**

Heyer, Wm. D., 523 South Broad St., Elizabeth, N. J. (33). **B D**

Hice, Richard R., Beaver, Pa. (51). **E**

Higdon, John Clark, 605 Union Trust Bldg., St. Louis, Mo. (50). **B D I**

Higgins, F. W., M. D., 20 Court St., Cortland, N. Y. (51). **K**

Higginson, James J., 16 E. 41st St., New York, N. Y. (49).

Higginson, John A., 260 Clarendon St., Boston, Mass. (50).

Higley, Hon. Warren, 68 West 40th St., New York, N. Y. (43).

Hildreth, John L., 14 Garden St., Cambridge, Mass. (50).

*Hilgard, Prof. E. W., Univ. of California, Berkeley, Cal. (11). 1874. **B C E**

Hill, Bruce V., Grinnell, Iowa. (48). **B**

Hill, Ebenezer, Treasurer, Norwalk Iron Works, South Norwalk, Conn. (50). **D**

*Hill, George A., U. S. Naval Observatory, Washington, D. C. (47). 1900. **A**

Hill, Gershom Hyde, Supt. State Hospital for the Insane, Independence, Iowa. (51). **K**

*Hill, John Edward, Prof. of Civil Engineering, Brown University, Providence, R. I. (44). 1897. D

*Hill, Robert Thomas, U. S. Geol. Survey, Washington, D. C. (36). 1889. E

Hillebrand, William F., U. S. Geological Survey, Washington, D. C. (51). E

Hillig, Frederick, J., S. J., Professor of Sciences, Canisius College, Buffalo, N. Y. (50).

Hillkowitz, Wm., M. D., 704 Race St., Cincinnati, Ohio. (50). C F I K

*Hillyer, Homer W., Ph. D., Chemical Laboratory, Univ. of Wisconsin, Madison, Wis. (42). 1896. C

Hilton, William A., 435 Penn Ave., Waverly, N. Y. (49). F

*Himes, Prof. Charles F., Carlisle, Pa. (29). 1882. B C

Hine, James S., Ohio State Univ., Columbus, Ohio. (48). F

*Hinrichs, Dr. Gustavus, 4106 Shenandoah Ave., St. Louis, Mo. (17). 1874. B C

Hinton, John H., M. D., 41 W. 32d St., New York, N. Y. (29). F H

Hirschberg, Michael H., Judge of Supreme Court, State of New York, Newburgh, N. Y. (50). I

Hirschfelder, Jos. Oakland, M. D., Professor of Cl. Med. Cooper Medical College, 1392 Geary St., San Francisco, Cal. (51). K

Hiss, P. Hanson, M. D., 28 Washington Square, N., New York, N. Y. (49). K

*Hitchcock, Albert Spear, Div. Agrostology, U. S. Dept. Agriculture, Washington, D. C. (39). 1892. G

Hitchcock, Miss Caroline Judson, Teacher in High School, Meriden, Conn. (50). B E

*HITCHCOCK, CHARLES H., Hanover, N. H. (11). 1874. E

Hitchcock, Embury A., 380 W. Eighth Ave., Columbus, Ohio. (48). D

Hitchcock, Miss Fanny R. M., 4038 Walnut St., Philadelphia, Pa. (35). F

*Hitchcock, Frank H., Chief Section Foreign Markets, U. S. Dept. Agriculture, Washington, D. C. (49). 1901. I

*Hitchcock, Romyn, Room 1804, 20 Broad St., New York, N. Y. (47). 1898. B C

*Hoadley, George A., Swarthmore College, Swarthmore, Pa. (40). 1900. B

Hoagland, Henry Williamson, M. D., 327 N. Nevada Ave., Colorado Springs, Colo. (51). F K

Hobbs, Prof. Perry L., Western Rerserve Medical College, Cleveland, Ohio. (41). C

*Hobbs, William Herbert, Ph. D., Madison, Wis. (41). 1893. E

Hobby, C. M., M. D., Iowa City, Iowa. (51). K

Hodge, Frederick Humbert, Professor of Mathematics, Bethel College, Russellville, Ky. (50). A

Hodge, James M., Big Stone Gap, Va. (29). D E

Hodges, Miss Julia, 217 W. 44th St., New York, N. Y. (36). E F H

Hodges, Thomas Edward, Professor of Physics, W. Va. State University, Morgantown, W. Va. (50). B

*Hodgkins, Prof. H. L., Columbian University, Washington, D. C. (40). 1896. A B

HOE, MRS. R., JR., 11 E. 36th St., New York, N. Y. (36).

Hoe, Mrs. Richard M., 11 E. 71st St., New York, N. Y. (36).

Hoffman, Christian B., Enterprise, Kansas. (50). D H

Hoffman, Very Rev. Eugene Aug., D. D., 1 Chelsea Square, New York, N. Y. (36).

*HOFFMANN, DR. FRIEDRICH, Charlottenburg, Kant St. 125, Berlin, Germany. (28). 1881. C F

Hogeboom, Miss Allen C., Shelbyville, Ky. (46). C

Holbrook, Henry R., Civil Engineer, Pueblo, Colo. (51). D

Holbrook, Percy, Genl. Mgr. Weber Ry. Joint Mfg Co., 145 W. 69th St., New York, N. Y. (51). D

Holbrow, Herman, L., Electrical Engineer, 112 Waverly Ave., Brooklyn, N. Y. (50). D

Holden, Edwin R., 13 E. 79th St., New York, N. Y. (49).

HOLDEN, MRS. L. E., The Hollenden, Cleveland, Ohio. (35).

Holferty, George M., Instructor in Botany, University of Illinois, Urbana, Ill. (50). G

*Holland, W. J., D. D., LL.D., Director Carnegie Museum, Pittsburg, Pa. (37). 1896. F

*Hollick, Arthur, N. Y. Botanical Garden, Bronx Park, New York, N. Y. (31). 1892. E G

Hollinshead, Warren H., Vanderbilt University, Nashville, Tenn. (37).

Hollister, John James, Mining Engineer, Gaviota, Santa Barbara Co., Cal. (50). E

Holmes, A. M., M. D., Jackson Block, Denver, Colo. (50). F K

Holmes, Dr. Christian R., 8–10 East Eighth St., Cincinnati, Ohio. (48).

Holmes, Frederic Harper, Instructor in Physics, Geography and Mathematics, State Normal School, Hyannis, Mass. (50). A B E

*Holmes, Prof. Joseph A., State Geologist, Chapel Hill, N. C. (33). 1887. E F

Holmes, Miss Mary S., 1331 Twelfth St., Philadelphia, Pa. (50). E

Holsinger, Samuel J., Special Agent, Interior Department, Phoenix, Arizona. (50). H

Holt, Chas., 255 W. 45th St., New York, N. Y. (51).

Holt, Edwin B., Trinity Court, Dartmouth St., Boston, Mass. (49).

Holt, Henry, 29 W. 23d St., New York, N. Y. (29).
Holt, Herbert S., President, Montreal Light, Heat and Power Co., Montreal, Can. (51). **D**
Holton, Henry D., M. D., Brattleboro, Vt. (44). **I**
Homburg, Frederick, Teacher of Chemistry, Woodward High School, Cincinnati, Ohio. (51). **C**
Homer, Charles S., Valentine & Co., 245 Broadway, New York, N. Y. (29).
Hoobler, Bert Raymond, Cornell University, Ithaca, N. Y. (50). **F G**
Hood, William, 512 Van Ness Ave., San Francisco, Cal. (35). **D**
Hooker, Donald R., Chemist, 1707 Fairmont Ave., Baltimore, Md. (50). **C K**
Hooker, Prof. Henrietta E., Mt. Holyoke College, South Hadley, Mass. (45). **G**
Hooper, Alcaeus, 710 Merchant's Bank, Baltimore, Md. (50). **I**
Hooper, Prof. Franklin W., Curator Brooklyn Institute, Brooklyn, N. Y. (43).
Hoover, William, Athens, Ohio. (49).
Hopeman, H., M. D., Minden, Neb. (51). **K**
*Hopkins, A. D., Ph. D., State University, Morgantown, W. Va. (42). 1899. **F**
*Hopkins, Prof. Arthur John, Amherst College, Amherst, Mass. (44). 1900. **C**
Hopkins, George B., 52 Broadway, New York, N. Y. (50).
Hopkins, George I., Manchester, N. H. (47). **A B**
*Hopkins, Grant S., Cornell University, Ithaca, N. Y. (41). 1900. **F**
*Hopkins, Nevil Monroe, Asst. Professor of Chemistry, Columbian University, Washington, D. C. (48). 1901. **C D**
*Hopkins, Thomas Cramer, Syracuse University, Syracuse, N. Y. (38). 1898. **E**
Hormell, Prof. William G., Ohio Wesleyan Univ., Delaware, Ohio. (48). **B**
Hornung, Christian, Professor of Mathematics and Astronomy, Heidelberg University, Tiffin, Ohio. (50). **A D**
*Horsford, Miss Cornelia, 27 Craigie St., Cambridge, Mass. (46). 1897. **H**
Hortvet, Julius, State Chemist, 1521 University Ave., S.E., Minneapolis, Minn. (50). **C**
Hoskins, William, La Grange, Ill. (34). **C**
Hosmer, Sidney, E. E., Boston Electric Light Co., 3 Head Place, Boston, Mass. (50). **D**
Hotchkiss, Henry Stuart, 55 Hillhouse Ave., New Haven, Conn. (50). **E I**
*Hough, Prof. G. W., Northwestern University, Evanston, Ill. (15). 1874. **A B D**

Hough, Theodore, Ph. D., Assistant Professor of Biology, Mass. Institute of Technology, Boston, Mass. (51). **K**

*Hough, Walter, U. S. National Museum, Washington, D. C. (38) 1890.

Houghton, Frederick, Public School, No. 7, Buffalo, N. Y. (51). **H**

Houk, Mrs. Eliza P. T., 41 W. Second St., Dayton, Ohio, (48).

Houser, Gilbert L., Ph. D., Professor Animal Morphology and Physiology, University of Iowa, Iowa City, Iowa. (50). **F K**

Houston, David Walker, M. D., Troy, N. Y. (51). **K**

*Hovey, Edmund O., Amer. Mus. Nat. History, Central Park, New York, N. Y. (36). 1895. **C E**

*Hovey, Rev. Horace C., 60 High St., Newburyport, Mass. (29). 1883. **E H**

Howard, Charles P., 116 Farmington Ave., Hartford, Conn. (51).

*Howard, Curtis C., 97 Jefferson Ave., Columbus, Ohio. (38). 1892. **C**

*Howard, Leland O., Ph. D., Cosmos Club, Washington, D. C. (37). 1889. **F**

Howard, Mrs. Leland O., 2026 Hillyer Place, N.W., Washington, D. C. (49). **H**

Howard, Orson, M. D., Professor of Biology, University of Utah, Salt Lake City, Utah. (50). **F K**

*Howard, S. Francis, Professor of Chemistry, Mass. Agricultural College, Amherst, Mass. (50). 1901. **C**

Howard, Wm. Lee, M. D., 1126 N. Calvert St., Baltimore, Md. (51). **K**

*Howe, Charles S., Case School of Applied Science, Cleveland, Ohio. (34). 1891. **A**

*Howe, Henry M., Professor of Metallurgy, Columbia University, New York, N. Y. (50). 1901. **D**

*Howe, Herbert Alonzo, Director of the Chamberlin Observatory, University of Denver, University Park, Colo. (50). 1901. **A**

*Howe, Prof. Jas. Lewis, Washington and Lee University, Lexington, Va. (36). 1888. **C**

Howe, J. Morgan, M. D., 12 West 46th St., New York, N. Y. (50).

Howe, Marshall A., New York Botanical Garden, Bronx Park, New York, N. Y. (49).

*Howell, Edwin E., 612 17th St., N.W., Washington, D. C. (25). 1891. **E**

Howell, John W., Ballantine Parkway, Newark, N. J. (50).

*Howell, William H., M. D., Professor of Physiology, Johns Hopkins University, Baltimore, Md. (50). 1901. **F K**

Howell, Wilson Stout, Sec'y Association of Edison Illuminating Companies, 14 Jay St., New York, N. Y. (50). **D**

Hower, Harry Sloan, Instructor in Physics, Case School of Applied Science, Cleveland, Ohio. (50). **B**

Howerth, Ira Woods, Instructor in Sociology, University of Chicago, Chicago, Ill. (50). **I**

Howland, Howard Newell, 116 S. 52d Ave., Chicago, Ill. (50). **F**

*Hrdlicka, Als, M. D., Amer. Mus. Nat. Hist., 77th St. and Central Park, West, New York, N. Y. (46). 1897. **H**

Hubbard, Walter C., Coffee Exchange Bldg., New York, N. Y. (49).

*Huber, G. Carl, M. D., Junior Professor of Anatomy and Director of Histological Laboratory, University of Michigan, Ann Arbor, Mich. (50). 1901. **F K**

Huddleston, John H., M. D., 126 West 85th St., New York, N. Y. (51). **K**

*Hudson, George H., Vice Principal, Dept. Natural Science, State Normal and Training School, Plattsburgh, N. Y. (31). 1901. **F**

Hull, Gordon Ferrie, Professor of Physics, Dartmouth College, Hanover, N. H. (50). **B**

Hume, Alfred, C. E., University Miss. (39). **A**

Hummel, John A., Experiment Station, St. Anthony Park, Minn. (48).

*Humphrey, Richard L., Testing Laboratory, City Hall, Philadelphia, Pa. (48). 1902. **D**

Humphreys, Alex. C., M. E., C. E., 31 Nassau St., New York, N. Y. (49).

Hungerford, W. S., care of W. Ames & Co., Jersey City, N. J. (43). **D**

Hunsicker, George W., 141 N. 8th St., Allentown, Pa. (50). **C**

Hunt, Chas. Wallace, Stapleton, N. Y. (51).

*Hunter, Andrew Frederick, Barrie, Ontario, Can. (38). 1896. **B H I**

Hunter, Chas. H., M. D., 13 Syndicate Block, Minneapolis, Minn. (51). **K**

*Hunter, Prof. Joseph Rufus, Richmond College, Richmond, Va. (45). 1899. **C**

Hunter, Samuel John, Associate Professor of Entomology, University of Kansas, Lawrence, Kansas (50). **F**

Hunter, Walter David, Special Agent, U. S. Department Agriculture, Washington, D. C. (50). **F**

Huntington, Edward Vermilye, Williams College, Williamstown, Mass. (47). **A**

Huntington, Ellsworth, Highland St., Milton, Mass. (51).

Hurd, E. O., Plainville, Ohio. (30). **E F**

Huxley, Henry Minor, Hotel Hunnewell, Newton, Mass. (48).

Hyams, Miss Isabel F., 26 Wales St., Dorchester, Mass. (47). **C**

Hyde, B. T. Babbitt, 20 W. 53d St. New York, N. Y. (43). **D**

Hyde, Charles Gilman, 6336 Burbridge St., Germantown, Pa. (47). **D**

Hyde, Miss Edith E., U. S. Nat'l Museum, Washington, D. C. (50). **H I**

Hyde, E. Francis, 835 Fifth Ave., New York, N. Y. (43). **A**

Hyde, Miss Elizabeth Mead, 210 E. 18th St., New York, N. Y. (49). **H**

*Hyde, E. W., Station D, Cincinnati, Ohio. (25). 1881. **A**

Hyde, Frederick E., M. D., 20 W. 53d St., New York, N. Y. (43). **E**

Hyde, Frederick E., Jr., 20 W. 53d St., New York, N. Y. (43). **H**

Hyde, Henry St. J., 210 E. 18th St., New York, N. Y. (49).

*Hyde, John, Statistician U. S. Dept. Agriculture, Washington, D. C. (47). 1898. **E I**

*Iddings, Joseph P., Univ. of Chicago, Chicago, Ill. (31). 1884. **E**

Iden, Thomas M., Professor of Chemistry and Physics, State Normal School, Emporia, Kansas. (50). **B C F**

*Iles, George, 5 Brunswick St., Montreal, Can. (31). 1898. **I**

Ill, Edward J., M. D., 1002 Broad St., Newark, N. J. (51). **K**

Ingham, Wm. A., 320 Walnut St., Philadelphia, Pa. (33). **E**

Ingram, Edward Lovering, C. E., Expert Aid, New York Navy Yard, New York, N. Y. (51). **A B C D**

Inslee, Mrs. Samuel, 50 W. 72d St., New York, N. Y. (49).

Iorns, Martin J., Mount Vernon, Ia. (50). **C G**

*Ives, Frederick E., 2750 N. 11th St., Philadelphia, Pa. (44). 1898. **B**

*Jack, John G., Jamaica Plain, Mass. (31). 1890. **G**

*Jackson, Prof. Charles L., Harvard University, Cambridge, Mass. (44). 1895. **C**

Jackson, John H., M. D., 155 Franklin St., Fall River, Mass. (51). **K**

*Jackson, Dr. Robert T., 33 Gloucester St., Boston, Mass. (37). 1890. **F**

Jackson, Victor H., M. D., D. D. S., 240 Lenox Ave., New York, N. Y. (51). **K**

Jacobs, Henry Barton, M. D., Instructor in Medicine, Johns Hopkins Medical School, Baltimore, Md. (50). **K**

Jacobs, Michael William, 222 Market St., Harrisburg, Pa. (50). **I**

*Jacobus, David S., Stevens Institute, Hoboken, N. J. (36). 1889. **A B D**

*Jacoby, Harold, Columbia University, New York, N. Y. (38). 1891. **A**

*Jacoby, Henry S., Prof. of Bridge Engineering and Graphics, Cornell University, Ithaca, N. Y. (36). 1892. **D**

Jaffa, Myer Edward, Berkeley, Cal. (47).

James, Bushrod W., A. M., LL.D., M. D., N.E. cor. 18th and Green Sts., Philadelphia, Pa. (29). **F**

James, Charles C., Dept. Agriculture, Toronto, Can. (46). **I**

James, Mrs. Sarah S., 1517 O St., N.W., Washington, D. C. (49). H I

*Jaques, Capt. William H., Little Boarshead, N. H. (47). 1899. D

Jarman, Joseph L., President and Prof. of Chemistry, State Female Normal School, Farmville, Va. (51). C

Jarvis, Samuel M., 1 West 72d St., New York, N. Y. (50).

*Jastrow, Dr. Joseph, Univ. of Wisconsin, Madison, Wis. (35). 1887. F H

*Jayne, Horace, 318 S. 19th St., Philadelphia, Pa. (29). 1884. F H

Jefferson, J. P., Manufacturer, Warren, Pa. (51). D I

Jefferis, Wm. W., 442 Central Park, West, New York, N. Y. (33). E

*Jeffries, B. Joy, M. D., 15 Chestnut St., Boston, Mass. (29). 1881. F H

Jelly, George Frederick, M. D., 69 Newbury St., Boston, Mass. (50). F K

*Jenkins, Edw. H., Drawer 101, New Haven, Conn. (33). 1885. C

Jenks, Albert E., Bureau of Ethnology, Washington, D. C. (50). H

*Jenks, Elisha T., Middleboro, Mass. (22). 1874. D

Jenks, Wm. H., Brookville, Pa. (38).

Jenks, William Johnson, Electrical Engineer, 120 Broadway, New York, N. Y. (50). B D

Jenney, Walter Proctor, E. M., Ph. D., Consulting Geologist and Mining Engineer, Knutsford Hotel, Salt Lake City, Utah. (50). E

Jennings, Gainor, M. D., West Milton, Ohio. (51). K

*Jennings, Walter L., Worcester Polytechnic Institute, Worcester, Mass. (45). 1898.

Jepson, Wm., M. D., Sioux City, Ia. (51). K

*Jesup, Prof. Henry G., Dartmouth College, Hanover, N. H. (36). 1891. F

Jesup, James R., 555 Fifth Ave., New York, N. Y. (50).

*Jesup, Morris K., 44 Pine St., New York, N. Y. (29). 1891. I

Jewell, Lewis E., Johns Hopkins University, Baltimore, Md. (49).

*Jewett, Prof. Frank Fanning, Oberlin College, Oberlin, Ohio. (47). 1899. C

Jewett, Geo. Franklin, M. D., Forman, N. Dak. (51). K

Johns, Carl, Instructor in Biology, Bethany College, Lindsborg, Kans. (50). F

Johnson, Albert Lincoln, C. E., 606 Century Bldg., St. Louis, Mo. (51). D

Johnson, Chas. Willison, Curator of Museum, Wagner Free Institute of Science, Philadelphia, Pa. (51).

Johnson, Frank Edgar, 747 Warburton Ave., Yonkers, N. Y. (50).

Johnson, Frank Seward, M. D., 2521 Prairie Ave., Chicago, Ill. (51). K

Johnson, Miss Isabel Louise, 467 Mass. Ave., Station A, Boston, Mass. (47). **E**

Johnson, John Benjamin, 708 East Colorado St., Pasadena, California. (51). **F**

Johnson, Nels, Manistee, Mich. (41). **A B**

*Johnson, Otis C., 730 Thayer St., Ann Arbor, Mich. (34). 1886. **C**

Johnson, Thomas Carskadon, 375 Spruce St., Morgantown, West Virginia. (51). **G**

Johnson, William Stone, Room 140, State House, Boston, Mass. (47). **D**

*Johnson, Willis Grant, 52 Lafayette Place, New York, N. Y. (47). 1901. **F**

Johnson, W. Smythe, Ph. D., Natchitoches, La. (49). **H**

Johnston, Geo. Ben., M. D., 407 E. Grace St., Richmond, Va. (51). **K**

Johnston, Thomas J., 66 Broadway, New York, N. Y. (50). **A B D**

Johnston, William A., Prince Bay, Borough of Richmond, N. Y. (50). **C**

Johnstone, William Bard, Assistant in Physics, Columbia University, New York, N. Y. (50). **B**

Johonnott, Edwin Sheldon, Ph. D., Rose Polytechnic Institute, Terre Haute, Ind. (50).

Jones, Charles C., M. D., Galveston, Texas. (50). **K**

Jones, Clement Ross, Professor Mechanical Engineering, West Virginia University, Morgantown, W. Va. (50). **D**

*Jones, Frederick S., Professor of Physics, University of Minnesota, Minneapolis, Minn. (45). 1901. **B**

*Jones, Lewis Ralph, Professor of Botany, University of Vermont, Burlington, Vt. (41). 1894. **G**

Jones, Lynds, M. Sc., Instructor in Zoology, Oberlin College, Oberlin, Ohio. (50). **F**

*Jones, Prof. Marcus E., Salt Lake City, Utah. (40). 1893. **G**

Jones, Philip Mills, M. D., 1710A, Stockton St., San Francisco, Cal. (50).

*Jordan, Prof. David Starr, President of Stanford University, Stanford University, Cal. (31). 1883. **F**

*Jordan, Edwin Oakes, Ph. D., University of Chicago, Chicago, Ill. (50). 1901. **K**

Jordan, Whitman H., Director N. Y. Agric. Exper. Station, Geneva, N. Y. (45).

Juat, Francis, M. D., Aberdeen, N. C. (50). **F K**

*Judd, Prof. Charles H., University of Cincinnati, Cincinnati, Ohio. (49). 1901. **H I**

*Julien, Alexis A., N. Y. Academy of Sciences, New York, N. Y. (24). 1875. **C E**

Just, John A., Chemist, 116 West Castle St., Syracuse, N. Y. (50). C

Kahl, Paul Hugo Isidor, State Inspector of Nurseries and Orchards, 903 California St., Urbana, Ill. (50). F.

*Kahlenberg, Louis, Ph. D., 306 Lake St., Madison, Wis. (46). 1898. C

Kahn, Julius, 100 West 80th St., New York, N. Y. (50). C

Kammerer, Jacob Andrae, 87 Jameson Ave., Toronto, Canada. (50). C D

Kann, Myer M., Station B, Pittsburg, Pa. (51).

Kaufmann, Paul, M. D., Professor of Bacteriology, Pathology, and Hygiene, State University, Columbia, Mo. (50). K

Kay, James I., 426 Diamond St., Pittsburg, Pa. (51). D I

Kay, Thomas Wiles, M. D., 345 Wyoming Ave., Scranton, Pa. (51). K

Kean, Mrs. Hamilton Fish, 25 East 37th St., New York, N. Y. (50).

Keane, John J., Rt. Rev., Archbishop of Dubuque, Dubuque, Ia. (51).

Kearney, Thomas H., Jr., U. S. Dept. Agriculture, Washington, D. C. (47). G

Keasbey, Lindley Miller, Professor of Economics and Politics, Bryn Mawr College, Bryn Mawr, Pa. (51). H I

Kedzie, John H., 1514 Ridge Ave., Evanston, Ill. (34). B

*Kedzie, Robert C., M. D., Professor of Chemistry, Agricultural College, Mich. (29). 1881. C

Keene, Geo. Fredk., M. D., Supt. State Hospital for the Insane, Howard, R. I. (51). K

*Keep, Wm. J., Detroit, Mich. (37). 1897.

Keilholtz, Pierre Otis, Consulting Engineer, Continental Trust Building, Baltimore, Md. (50). D

Keim, Edward Tudor, E. E., Supt. Am. Dist. Tel. Co., 1447 Lawrence St., Denver, Colo. (50). D F

Keith, Prof. Marcia A., Mount Holyoke College, South Hadley, Mass. (46). B

Keller, Edward, Ph. D., Box 724, Baltimore, Md. (50). C D

Keller, Emil E., P. O. Box 452, Pittsburg, Pa. (51).

*Kellerman, Prof. William A., Ohio State University, Columbus, Ohio. (41). 1893. G

Kelley, John Harris, 315 N. Vine St., Nashville, Tenn. (44). C

Kelley, Walter S., Mining Engineer, Leadville, Colo. (50). D

Kellogg, John H., M. D., Battle Creek, Mich. (24). F

*Kellogg, Vernon Lyman, Professor of Entomology, Stanford University, California. (50). 1901. F

Kelly, John F., Ph. D., Consulting Electrical Engineer, 284 W. Housatonic St., Pittsfield, Mass. (50). D

Kelly, William, Mining Engineer, General Manager Penn. Iron Mining Co., Vulcan, Mich. (50). D E

Kelsey, Harlan Page, 1150 Tremont Building, Boston, Mass. (47). G

Kelsey, James A., Agric. Exper. Station, New Brunswick, N. J. (49).

*Kemp, James F., School of Mines, Columbia University, New York, N. Y. (36). 1888. E

Kendall, Francis Drake, M. D., 1309 Plain St., Columbia, So. Carolina. (51). K

Kendall, Hugh F., Mining Engineer, The Interstate Mining Co., Virginia, Minn. (50). E

Kendig, Rev. A. B., D. D., 86 Vernon St., Brookline, Mass. (49).

*Kendrick, Arthur, Electrical Measuring Instruments, 45 Hunnewell Ave. Newton, Mass. (45). 1897. B

Kennedy, Frank Lowell, Instructor in Lawrence Scientific School, Harvard University, Cambridge, Mass. (50).

Kennedy, Dr. George Golding, Readville, Mass. (40). F G

KENNEDY, HARRIS, 284 Warren St., Roxbury, Mass. (40). E F

*Kennelly, Arthur Edwin, Sc. D., Electrical Engineer, Crozer Building, Philadelphia, Pa. (50). 1901. D

Kent, James Martin, Instructor in Steam and Electricity, Manual Training High School, Kansas City, Mo. (50). D E

Kent, Norton Adams, Ph. D., Yerkes Observatory, Williams Bay, Wis. (50). A

*Kent, William, Passaic, N. J. (26). 1881. D I

Kenyon, Oscar Curtis, Teacher of Physics, High School, Syracuse, N. Y. (50). B

Kepner, Harry V., Instructor in Chemistry, Manual Training High School, Denver, Colo. (50). C

Keppel, F. P., Secretary of Columbia University, West 116th St., New York, N. Y. (51).

Keppler, Rudolph, 28 W. 70th St., New York, N. Y. (49).

Kern, Josiah Quincy, Ph. D., 507 6th St., N.W., Washington, D. C. (40). I

Kern, Walter McCullough, Supt. Public Schools, Columbus, Neb. (50). F G

*Kershner, Prof. Jefferson E., Lancaster, Pa. (29). 1883. A B

Kesler, John Louis, Prof. of Natural Science, Baptist Female University, Raleigh, N. C. (51). F

Kester, Fred. Edward, Ohio State University, Columbus, Ohio. (48). B

Ketchum, Alexander P., 32 Mt. Morris Park, W., New York, N. Y. (49).

*Keyser, Cassius Jackson, Instructor in Mathematics, Columbia University, New York, N. Y. (50). 1901. A

Kimball, Albert B., M. E., Central High School, Springfield, Mass. (47). B

*Kimball, Arthur Lalanne, Professor of Physics, Amherst College, Amherst, Mass. (50). 1901. B

Kimball, Edwin Boyce, Mining Engineer, Oroville, Cal. (50). D

Kimball, S. I., Life Saving Service, U. S. Treasury Dept., Washington, D. C. (49). I

Kindle, Dr. Edward M., Geologist, 109 Elm St., New Haven, Conn. (50). E

*Kinealy, John H., Washington University, St. Louis, Mo. (36). 1891. D

*King, A. F. A., M. D., 1315 Mass. Ave., N.W., Washington, D. C. (29). 1900. F H

King, Cyrus A., Ph. D., Instructor in Botany, University of Indiana, Bloomington, Ind. (50). G

*King, F. H., 205 9th St., S.W., Washington, D. C. (32). 1892. E F

King, George B., Lawrence, Mass. (47).

*Kingsbury, Albert, Professor of Applied Mechanics, Worcester Polytechnic Institute, Worcester, Mass. (43). 1898. D

*Kingsbury, Benj. F., Ithaca, N. Y. (45). 1899. F

Kinner, Hugo, M. D., 1103 Rutger St., St. Louis, Mo. (21). F H

Kinney, Charles Noyes, Professor of Chemistry, Drake University, Des Moines, Iowa. (50). C

Kinney, Julius Eugene, M. D., 1427 Stout St., Denver, Colo. (51). K

*Kinnicutt, Dr. Leonard P., 77 Elm St., Worcester, Mass. (28). 1883. C

Kinraid, Thomas Burton, 38 Spring Park Avenue, Jamaica Plain, Mass. (47).

Kinsley, Carl, Quadrangle Club, Chicago, Ill. (47). B

Kirk, Arthur, 910 Duquesne Way, Pittsburg, Pa. (50). E I

Kirk, Elliott W., Wesley Hall, Nashville, Tenn. (50). F G

Kirkpatrick, E. A., Fitchburg, Mass. (49). H I

Kirkpartick, Samuel, M. D., Selma, Ala. (51). K

Kirkwood, Joseph E., Instructor in Botany, Syracuse University, Syracuse, N. Y. (51). G

*Kirschmann, A., Ph. D., Toronto University, Toronto, Can. (50). 1901. H K

Kittredge, Miss H. A., North Andover, Mass. (37). F

Klebs, Arnold C., M. D., 706, 100 State St., Chicago, Ill. (51). K

Klepetko, Frank, Manager Reduction Works of Anaconda Copper Mining Co., Butte, Mont. (50). D

Kletzsch, Gustav A., M. D., 453 Cass St., Milwaukee, Wis. (51). K

Klie, G. H., Chas. M. D., 5100 N. Broadway, St. Louis, Mo. (39). C F

Klingensmith, Israel P., M. D., Blairsville, Pa. (51). K
*Klotz, Otto Julius, 437 Albert St., Ottawa, Can. (38). 1889.
Knapp, Alfred A., M. D., Brimfield, Peoria Co., Ill. (51). K
Knapp, G. N., Stanton, Minn. (46). G H
Knauff, Francis Henry, Oak Lane, Philadelphia, Pa. (51). D
Knerr, Ellsworth B., Sc. D., Midland College, Atchison, Kas. (51).
Knight, Prof. Charles M., 219 S. Union St., Akron, Ohio. (29). B C
Knight, Wm. H., President So. California Academy of Sciences, 2 Bryson Block, Los Angeles, Cal. (51). A
*Knipp, Charles Tobias, Indiana University, Bloomington, Ind. (46). 1900. B
Knowles, Morris, Resident Engineer, Bureau of Filtration, 5656 Callowhill St., Pittsburg, Pa. (51). D
Knox, Francis H., Electrical Engineer, Spartanburg, S. C. (50). D
Knox, Henry H., Mining Engineer, 110 East 23d St., New York, N. Y. (50). D
Knox, S. L. Griswold, General Electric Co., Schenectady, N. Y. (50) D
*Kober, Geo. Martin, M. D., 1600 T St., N.W., Washington, D. C. (40). 1896. H
Koenig, Adolph, M. D., Editor "Penna. Medical Journal," 122 Ninth St., Pittsburg, Pa. (50). F G K
*Kofoid, Prof. Charles Atwood, University of California, Berkeley, Cal. (48). 1899. F
Kohnke, Quitman, M. D., Chairman and Health Officer, Board of Health, Cora Building, New Orleans, La. (51). K
Kolbenheyer, Fred'k, M. D., 2006' Lafayette Ave., St. Louis, Mo. (51). K
Koues, Miss Elizabeth L., 282 W. 85th St., New York, N. Y. (41). I
*KRAEMER, PROF. HENRY, 145 N. 10th St., Philadelphia, Pa. (47). 1901. G
Kraus, Edward H., Syracuse University, Syracuse, N. Y. (50). E
Krause, Otto H., Prospect Ave., Hackensack, N. J. (50).
Krécsy, Prof. Béla, VI Bulyovsxky u. 22, Budapest, Hungary. (41). C
*Kremers, Prof. Edward, University of Wisconsin, Madison, Wis. (47). 1901. C
Kretz, Prof. Charles Henry, Asst. Professor Mechanical Engineering, La. State University and A. and M. College, Baton Rouge, La. (50). D
*Kroeber, A. L., Ph. D., Univ. of California, Berkeley, Cal. (47). 1901. H
Kuhne, F. W., 19 Court St., Fort Wayne, Ind. (38). A F
Kummer, Frederic Arnold, Civil Engineer, President, United States Wood Preserving Co., 29 Broadway, New York, N. Y. (51). D

Kunhardt, Wheaton B., 1 Broadway, New York, N. Y. (49).
Kuntze, Dr. Otto, Villa Girola, San Remo, Italy. (49).
*Kunz, G. F., care of Messrs. Tiffany & Co., Union Square, New York, N. Y. (29). 1883. **C E H**
*Lachman, Arthur, Ph. D., Professor of Chemistry and Dean of College of Science and Engineering, University of Oregon, Eugene, Oregon. (50). 1901. **C D**
*Ladd, Prof. E. F., Agricultural College, Fargo, No. Dakota. (36). 1889. **C**
Ladd, George Tallman, care Bass Foundry and Machine Co., Fort Wayne, Ind. (51).
La Fetra, Linnaeus Edford, M. D., 58 West 58th St., New York, N. Y. (50). **F H K**
*Laflamme, Prof. J. C. K., Laval University, Quebec, Can. (29). 1887. **B E**
*La Flesche, Francis, 214 First St., S.E., Washington, D. C. (33). 1885. **H**
*Lamb, Daniel S., M. D., 800 10th St., N.W., Washington, D. C. (40). 1894. **H**
*Lambert, Preston A., 215 S. Center St., Bethlehem, Pa. (41). 1896. **A**
Lampard, Henry, 102 Shuter St., Montreal, Can. (40). **C D E**
Lancaster, Walter B., M. D., 101 Newbury St., Boston, Mass. (51). **K**
Landes, Henry, State Geologist, Seattle, Wash. (51). **E**
Landis, W. W., Dickinson College, Carlisle, Pa. (50).
Landon, Francis C., Staatsburg-on-Hudson, N. Y. (50).
*Landreth, Olin H., Union College, Schenectady, N. Y. (28). 1883. **D**
Lane, Alfred C., State Geologist, Lansing, Mich. (50). **E**
Lane, Horace Manley, M. D., Caixa 14 S. Paulo, Brazil, South America. (46).
Lang, Prof. Henry R., Yale University, New Haven, Conn. (41). **H**
Lange, J. D., 220 W. 79th St., New York, N. Y. (49).
Lange, Philip A., Supt. Westinghouse Elec. and Mfg. Co., Pittsburg, Pa. (50). **D**
*Langenbeck, Karl, 27 Orchard St., Zanesville, Ohio. (39). 1896. **C**
*Langley, Prof. S. P., Smithsonian Institution, Washington, D. C. (18). 1874. **A B**
Langmann, Gustav, M. D., 121 W. 57th St., New York, N. Y. (36).
Langsdorf, Alexander Suss, Instructor in Physics and Electrical Engineering, Washington University, St. Louis, Mo. (50). **B D**
Lanneau, John Francis, Professor of Applied Mathematics and Astronomy, Wake Forest College, Wake Forest, N. C. (50). **A B D**
Lanphear, Burton S., Asst. Professor of Electrical Engineering, Iowa State College, Ames, Ia. (51). **D**

*Lanza, Prof. Gaetano, Mass. Institute Technology, Boston, Mass. (29). 1882. A B D

Laramy, Robert Edward, Teacher in Moravian School, 27 North New St., Bethlehem, Pa. (51). E

Lare, H. S. P., M. D., 3452 Park Ave., St. Louis, Mo. (49).

LARKINS, EDGAR L., Director of Lowe Observatory, Echo Mountain, Cal. (51). A

La Rue, Wm. Gordon, North Freedom, Wis. (50). D E

Lathbury, B. Brentnall, C. E., Consulting Chemist, 1619 Filbert St., Philadelphia, Pa. (51). B.

Latimer, Thos. S., M. D., 211 W. Monument St., Baltimore, Md. (50). F H K

*Lattimore, Prof. S. A., University of Rochester, Rochester, N. Y. (15). 1874. C

Lauder, George, 7403 Penn Avenue, Pittsburg, Pa. (50).

*Laudy, Louis H., Ph. D., School of Mines, Columbia University, New York, N. Y. (28). 1890. C

Lauman, George Nieman, Instructor in Horticulture, Cornell University, Ithaca, N. Y. (50). G

Law, Benedict W., 693 Lafayette Ave., Brooklyn, N. Y. (45). E

Lawrance, J. P. S., Past Assistant Engineer U. S. N., Navy Dept., Washington, D. C. (35). D

Lawrence, A. E., 1 W. 81st St., New York, N. Y. (49).

Lawrence, Harry E., Univ. of Rochester, Rochester, N. Y. (44). B

Lawrence, James W., Professor of Mechanical Engineering, Agricultural College, Fort Collins, Colo. (50). D

Laws, Frank Arthur, Mass. Institute Technology, Boston, Mass. (47).

*Lawson, Andrew C., Professor of Geology and Mineralogy, University of California, Berkeley, Cal. (50). 1901. E

Lay, Henry Champlin, Civil and Mining Engineer and Geologist, U. S. Deputy Mineral Surveyor, Telluride, Colo. (51). D E

Lazell, Ellis W., Ph. D., 1619 Filbert St., Philadelphia, Pa. (51). C

*Leach, Miss Mary F., 502 Forest Ave., Ann Arbor, Mich. (44). 1896. C

*Leaming, Edward, 437 West 59th St., New York, N. Y. (50). 1901. C

Leathers, W. S., Professor of Biology, University of Mississippi, University P. O., Miss. (50). F

Leavitt, Frank M., Mechanical Engineer, 258 Broadway, New York, N. Y. (51). D

Le Boutillier, Roberts, E. Washington Avenue, Germantown, Philadelphia, Pa. (47). G

*Le Brun, Mrs. Michel M., 8 Mountain Ave., S., Montclair, N. J. (35). 1892. F

Le Conte, Robert Grier, M. D., 1625 Spruce St., Philadelphia, Pa. (51). K

Le Conte, Louis Julian, Civil Engineer, P. O. Box 482, Oakland, Cal. (51). D

*Ledoux, Albert R., Ph. D., 99 John St., New York, N. Y. (26). 1881. C

Lee, Francis Valentine T., Electrical Engineer, 31 and 33 New Montgomery St., San Francisco, Cal. (50). D

*Lee, Frederic S., Adjunct Professor of Physiology, Columbia University, New York, N. Y. (49). 1901. K

Lee, Waldemar, Passaic, N. J. (50).

Lee, William George, Harvard Medical School, Boston, Mass. (50). H K

Lee, Prof. Willis Thomas, Trinidad, Colo. (47). E F

Leeds, Morris E., 3221 North 17th St., Philadelphia, Pa. (50). D

*Lefavour, Prof. Henry, The Westminster, Boston, Mass. (42). 1894.

Le Grand, Leroy, M. D., Graham, Texas. (50). F K

*Lehmann, G. W., Ph. D., City Hall Annex, Baltimore, Md. (30). 1885. B C

Lehnartz, W., 173 S. Union St., Grand Rapids, Mich. (51).

Leidy, Joseph, Jr., M. D., 1319 Locust St., Philadelphia, Pa. (51). K

Leisen, Theo. Alfred, Civil Engineer, Wilmington, Del. (51). B C D G

Leiter, L. Z., 81 South Clark St., Chicago, Ill (40).

Lemley, C. McC., Asst. Engineer, B. & O. R.R. Co., Philippi, W. Va. (51). D

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Lender, Mrs. Julia A., 2201 Lincoln Ave., Denver, Colo. (50). A B

Lengfeld, Felix, Ph. D., Consulting and Manufacturing Chemist, 202 Stockton St., San Francisco, Cal. (51). C

*Lennon, William H., Brockport, N. Y. (31). 1894. C G

Leonard, Chas. Lester, M. D., 1930 Chestnut St., Philadelphia, Pa. (51). K

Leonard, John William, Editor of "Who's Who in America," Wheaton, Ill. (50). I

Leonard, Percy Allan, Editor of "Ores and Metals," P. O. Box 364, Denver, Colo. (50). E

Le Rossignol, James Edward, Ph. D., Professor of Economies, University of Denver, University Park, Colo. (50). I

*Lesley, Prof. J. Peter, P. O. Box 93, Milton, Mass. (2). 1874. E

Leslie, Miss Augusta, Newburgh, N. Y. (50). I

Letson, Miss Elizabeth J., 366 Mass. Ave., Buffalo, N. Y. (47).

*Leverett, Frank, Ann Arbor, Mich. (37). 1891. E

• Levine, Edmund J., The Fiberloid Co., 638 Broadway, New York, N. Y. (49).

LEWIS, CLARENCE MCKENZIE, care Chief Engineer, B. & O. R.R., Baltimore, Md. (47). D

Lewis, George Smith, 746 State St., Springfield, Mass. (44). G

Lewis, Howard W., Banker, 1928 Spruce St., Philadelphia, Pa. (51). I

*Lewis, Joseph Volney, Professor of Geology, Clemson College, S. C. (45). 1900. C E

Lewis, Wilfred, Pres. The Tabor Mfg. Co., 5901 Drexel Road, Philadelphia, Pa. (51). D

*Libbey, Prof. William, Princeton, N. J. (29). 1887. E F

Lichthardt, G., Jr., 18th and M Sts., Sacramento, Cal. (50).

Lichty, Milton J., M. D., Cor. Genesee St. and Hough Ave., Cleveland, Ohio. (50). F K

Lightfoot, Thos. Montgomery, Asst. Prof. of Physical Science, Central High School, Philadelphia, Pa. (51). G

*Lillie, Frank R., Professor of Zoology, University of Chicago, Chicago, Ill. (50). 1901. F

Lincoln, Paul Martyn, Electrical Engineer, care Niagara Falls Power Co., Niagara Falls, N. Y. (50). D

*Lindenkohl, Adolphus, U. S. C. and G. Survey, Washington, D. C. (40). 1898. E

Lindenkohl, Henry, U. S. C. and G. Survey, Washington, D. C. (47).

*Lindenthal, Gustav., C. E., 45 Cedar St., New York, N. Y. (37). 1891. I

Linder, Oliver A., 35 Clark St., Chicago, Ill. (49).

Lindsay, Alexander M., Rochester, N. Y. (41).

Lindsey, Edward, Warren, Pa. (48). H

*Ling, Charles Joseph, Instructor in Physics, Manual Training High School, Denver, Colo, (50). 1901. A B

*Linn, Alvin Frank, Ph. D., Professor of Chemistry, Wittenberg College, Springfield, Ohio. (50). 1901. C

Linn, George A., M. D., Monogahela, Pa. (51). K

Linville, Henry, R., 509 West 112th St., New York, N. Y. (49).

Lion, Léon Elie, C. E., Assistant on U. S. Engineer Corps, 1010 Burgundy St., New Orleans, La. (51). D

Littell, Frank B., U. S. Naval Observatory, Washington, D. C. (49).

Little, C. A., Analyst at Lorain Steel Works, Box 517, Elyria, Ohio. (50). D

Little, Henry P., Superintendent of Union Schools, Momence, Ill. (50). B

Livermore, Mrs. M. A. C., 59 Brewster St., Cambridge, Mass. (29). F

Lloyd, Andrew J., 310 Boylston St., Boston, Mass. (47). **B H**
*Lloyd, Francis E., Teachers' College, Columbia University, New York, N. Y. (48). 1901. **G**
*Lloyd, John Uri, Court and Plum Sts., Cincinnati, Ohio. (38). 1890. **C F**
Lloyd, Thomas Mortimer, M. D., 125 Pierrepont St., Brooklyn, N. Y. (51). **K**
Lobenstine, William C., 245 Central Park, W., New York, N. Y. (49).
Lochhead, William, Professor of Biology, Ontario Agricultural College, Guelph, Ontario, Can. (51). **F**
Lockwood, Cornelius Wygant, Teacher of Science, Newburgh Academy, Newburgh, N. Y. (50). **B E**
Lockwood, Edwin Hoyt, Asst. Prof. Mechanical Engineering, Yale University, New Haven, Conn. (50). **D**
*Loeb, Morris, Ph. D., 118 W. 72d St., New York, N. Y. (36). 1889. **C**
Loeb, Leo, M. D., Gratwick Research Laboratory, University of Buffalo, Buffalo, N. Y. (51). **K**
*Loew, Dr. Oscar, Komaba, Tokyo, Japan. (49). 1900. **G**
Loewy, Benno, 206 and 208 Broadway, New York, N. Y. (41).
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LOGAN, WALTER S., 27 William St., New York, N. Y. (36).
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Lomb, Henry, P. O. Drawer 1033, Rochester, N. Y. (41).
Lomb, Henry C., P. O. Drawer 1033, Rochester, N. Y. (43).
*Long, Prof. John H., 2421 Dearborn St., Chicago, Ill. (41). 1895. **C**
Long, William Henry, Jr., Denton, Texas. (50).
*Longden, A. C., Ph. D., Professor of Physics, Knox College, Galesburg, Ill. (49). 1901. **B**
Loomis, Frederick B., Ph. D., Assistant in Zoology, Amherst College, Amherst, Mass. (50). **F**
Lord, Benjamin, 34 W. 28th St., New York, N. Y. (36).
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*Loud, Frank H., Colorado Springs, Colo. (29). 1890. **A B**
Louderback, George Davis, Professor of Geology, Nevada State University, Renó, Nev. (50). **E**
*Lough, J. E., New York University, Washington Square, New York, N. Y. (50). 1901. **I**
*Loughridge, Dr. R. H., Univ. of California, Berkeley, Cal. (21). 1874. **C E**
*Love, Edward G., 80 E. 55th St., New York, N. Y. (24). 1882. **C**
Lovejoy, J. R., Genl. Elec. Co., Schenectady, N. Y. (50). **D**
LOVELAND, HORACE HALL, M. D., Michigamme, Mich. (51). **K**
*Lovett, Edgar Odell, Professor of Mathematics, Princeton University, Princeton, N. J. (51). 1902. **A**

Low, A. A., Columbia Heights, Brooklyn, N. Y. (43). A.

*Low, Seth, Mayor of City of New York, New York, N. Y. (29). 1890.

Lowber, Rev. James William. Ph. D., 113 East 18th St., Austin, Texas. (50). I

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*Lowell, Percival, 53 State St., Boston, Mass. (36). 1896. A

Lowell, Russell C., 167 Ohio Ave., Providence, R. I. (51).

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Luckey, John Eddy, M. D., Vinton, Ia., (51). I K

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Luebkert, Otto J. J., U. S. Dept. Agriculture, Washington, D. C. (50). G

Lufkin, Albert, Newton, Iowa. (31). D E

Loll, Richard S., Amherst, Mass. (43). F H

Lund, James, 142 Hawthorne St., Malden, Mass. (45).

Lundin, Carl A. R., care Messrs. Alvan Clark and Sons, Cambridgeport, Mass. (47). A

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*Lyford, Edwin F., Springfield, Mass. (33). 1896. B C H

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LYMAN, BENJ. SMITH, 708 Locust St., Philadelphia, Pa. (15). E

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Lyman, James, Assist. Engineer, Genl. Elec. Co., 1047 Monadnock Bldg., Chicago, Ill. (50). D

Lyons, Albert Brown, M. D., Consulting Chemist, 72 Brainard St., Detroit, Mich. (50). C K

*Mabery, Prof. C. F., Case School of Applied Science, Cleveland, Ohio. (29). 1881. C

McAdam, D. J., Teacher of Mathematics, Washington and Jefferson College, Washington, Pa. (51). A

McAlpin, C. W., 11 East 90th St., New York, N. Y. (50).

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McArthur, Lewis L., M. D., 100 State St., Chicago, Ill. (51). K

Macbeth, George A., Trustee Carnegie Institute, Pittsburg, Pa. (50). D H

McBride, Hon. George Wickliffe, U. S. Comm'r La. Purchase Exposition, P. O. Box 173, Washington, D. C. (51). **I**

McBride, Jas. H., M. D., Pasadena, Cal. (51). **K**

*Macbride, Thomas H., Iowa City, Iowa. (38). 1890. **G**

McCalley, Henry, Chief Assist. State Geologist, University, Ala. (50). **E**

McCartney, Dr. James H., Room 501 Granite Building, Rochester, N. Y. (41). **A B**

*McCauley, C. A. H., Colonel and Deputy Quartermaster-General, U. S. A., Manila, P. I. (29). 1881.

McClelland, James H., M. D., 5th and Wilkins Aves., Pittsburg, Pa. (50). **F K**

*McClintock, Emory, Morristown, N. J. (43). 1895. **A**

McCormick, Henry Dreer, M. D., Resident Physician, Branch Hospital for the Insane, Verona, N. J. (51). **K**

McCoy, Lucinus S., Whitten, Hardin Co., Iowa. (50). **A**

*McCreath, Andrew S., 223 Market St., Harrisburg, Pa. (33). 1889. **C E**

McCune, M. Virginia, M. D., 506 West John St., Martinsburg, W. Va. (51). **K**

*McCurdy, Charles W., Ph. D., Witherspoon Building, Philadelphia, Pa. (35). 1895. **E F**

*MacCurdy, George Grant, Ph. D., 237 Church St., New Haven, Conn. (48). 1900. **H**

McCurdy, Hansford M., Manual Training High School, Kansas City, Mo. (51). **F G**

McDermott, Rev. P. A., Pittsburg College of the Holy Ghost, Bluff and Cooper Sts., Pittsburg, Pa. (51).

Macdonald, Benjamin J., 296 Grand St., Newburgh, N. Y. (50). **I**

McDonnell, Curtis C., Asst. Chemist Agric. Exper. Station, Clemson College, S. C. (51). **C**

*McDonnell, Prof. Henry B., College Park, Md. (40). 1893. **C**

*MacDougal, Daniel T., N. Y. Botanical Garden, Bronx Park, New York, N. Y. (44). 1897. **G**

MacDougall, George R., 131 West 73d St., New York, N. Y. (49).

*MacDougall, Robert, Ph. D., Sedgwick Park, University Heights, New York, N. Y. (49). 1901. **H K**

McFadden, L. H., Westerville, Ohio. (32). **B C**

McFadden, Thomas Gilbert, Lebanon Valley Coll., Annville, Pa. (48). **C**

MacFarland, W. W., 22 William St., New York, N. Y. (49).

*Macfarlane, A., Lehigh University, S. Bethlehem, Pa. (34). 1886. **A B**

Macfarlane, James R., President Academy of Science and Art, Pittsburg, Pa. (50). **E**

*Macfarlane, John M., Lansdowne, Pa. (41). 1899. **F G**

McGahan, Chas. F., M. D., Aiken, S. C. (51). K

*McGee, Dr. Anita Newcomb, 1901 Baltimore St., Washington, D. C. (37). 1892. H

McGee, D. W., Farley, Iowa. (50). E

McGee, Miss Emma R., Box 197, Farley, Iowa. (33). H

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*McGee, W J, Ph. D., Bureau Amer. Ethnology, Washington, D. C. (27). 1882. E H

*McGill, John T., Ph. D., Vanderbilt University, Nashville, Tenn. (36). 1888. C

McGinnis, W. H., 1020 Orange St., Youngstown, Ohio. (48).

*McGregory, Prof. J. F., Colgate University, Hamilton, N. Y. (35). 1892. C

*McGuire, Joseph D., 1908 Sunderland Place, Washington, D. C. (51). 1902. H

MacIntyre, Miss Lucy, 303 West 74th St., New York, N. Y. (49).

Mack, Jacob W., 92 Liberty St., New York, N. Y. (49).

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McKee, George C., care The Wm. Tod Co., Youngstown, Ohio. (48). A B D

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McKenney, Randolph Evans Bender, Ph. D., Department of Agriculture, Washington, D. C. (51). G

McKeown, W. W., Jr., Mining Engineer, Room 607, No. 160 Washington St., Chicago, Ill. (51). D E

McKinney, Thomas Emery, Professor of Mathematics and Astronomy, Marietta College, Marietta, Ohio. (50). A

McLain, Louis Randolph, Pres. of Florida Engineering Co., St. Augustine, Fla. (51). D

McLanahan, George William, 1601 21st St. N.W., Washington, D. C. (50).

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McLaury, Howard L., Prof. of Mathematics and Physics, So. Dakota School of Mines, Rapid City, So. Dak. (50). A B

McLean, Simon James, Ph. D., Professor of Economics and Sociology, University of Arkansas, Fayetteville, Ark. (51). I

McLennan, J. C., Professor of Physics, Toronto University, Toronto, Ontario, Can. (51). B

McLimont, Andrew Wingate, Electrical Engineer, Linares, Nuevo Leon, Mexico. (51). D

*Macloskie, Prof. George, Princeton Univ., Princeton, N. J. (25). 1882. F G

McMahan, Charles Hays, E. M., Supt. Sombrerete Mining Co., Sombrerete, Zacatecas, Mexico. (50). E

*McMahon, Prof. James, Cornell University, Ithaca, N. Y. (36). 1891. A

McMILLAN, SMITH B., Signal, Ohio. (37).

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McNair, Fred Walter, President Michigan College of Mines, Houghton, Michigan. (51). B D

McNeil, Hiram Colver, Teacher of Chemistry and Physics, Shurtleff College, Upper Alton, Ill. (51). B C

*McNeill, Malcolm, Professor Mathematics and Astronomy, Lake Forest University, Lake Forest, Ill. (32). 1885. A

MacNeille, Perry Robinson, 155 William St., Orange, N. J. (51).

McNulty, Geo. Washington, Civil Engineer, 258 Broadway, New York, N. Y. (51). D

McNulty, John J., Ph. D., College of City of New York, New York, N. Y. (50).

*MacNutt, Barry, Lehigh University, So. Bethlehem, Pa. (47). 1900. B

*McPherson, Prof. Wm., Ohio State Univ., Columbus, Ohio. (45). 1898. C

McPherson, William D., 58 Hartford St., So. Framingham, Mass. (47).

McQueeney, Francis J., M. D., 46 Dartmouth St., Boston, Mass. (51). K

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Magee, Jas. Francis, 114 N. 17th St., Philadelphia, Pa. (51). C

Magee, Louis J., Electrical Engineer, Grosse Quer Allee 1, Berlin, Germany. (50). B D

*Magie, Prof. Wm. Francis, Princeton University, Princeton, N. J. (35). 1887.

Magnusson, Carl Edward, Ph. D., Prof. of Physics, University of New Mexico, Albuquerque, N. M. (51). D

Magruder, Egbert W., Chemist, Department of Agriculture, Richmond, Va. (51). C

*Magruder, Wm. T., Ohio State Univ., Columbus, Ohio. (37). 1899.

Mahin, John William, Teacher in Manual Training High School, Denver, Colo. (50). B C E

Mahoney, Stephen R., M. D., 206 Maple St., Holyoke, Mass. (51). K

Makuen, G. Hudson, M. D., 1419 Walnut St., Philadelphia, Pa. (51). K

Mallinckrodt, Edw., P. O. Sub-Station A, St. Louis, Mo. (29). C

Mally, Charles William, Dept. Agric., Cape Town, So. Africa. (46).
Mally, Fred'k William, Prof. of Entomology, Agric. and Mech. College, College Station, Tex. (50). **F G**
Malm, John Lawrence, Marysville, Mont. (50). **C E**
*Maltby, Margaret E., Ph. D., Barnard College, New York, N. Y. (46). 1898.
Mangan, Daniel C., M. D., 95 Park Ave., Brooklyn, N. Y. (50). **F K**
Manley, Thomas Henry, M. D., 115 West 49th St., New York, N. Y. (51). **K**
Mann, Albert, Ph. D., 506 Westcott St., Syracuse, N. Y. (43). **G**
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Mann, Thomas Wm., 35 Hampden St., Holyoke, Mass. (44). **D**
Manning, Charles H., U. S. N., Manchester, N. H. (35). **D**
Manning, J. Woodward, 1150 Tremont Building, Boston, Mass. (47). **G**
Manning, Warren H., Brookline, Mass. (31). **E F H**
Mansfield, Albert K., 125 Lincoln Ave., Salem, Ohio. (51). **D**
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Mapes, Charles Victor, 60 W. 40th St., New York, N. Y. (37). **C**
Marble, J. Russel, Worcester, Mass. (31). **C E**
MARBLE, MANTON, Bedford, N. Y. (36).
Marble, Milton M., Instructor in Physics, Hillhouse High School, New Haven, Conn. (50). **B**
Marble, Miss Sarah, Woonsocket, R. I. (29). **C**
Marc, Theophilus M., 359 Produce Exchange, New York, N. Y. (49).
*Marindin, Henry Louis, U. S. C. and G. Survey, Washington, D. C. (40). 1898. **E**
*Mark, Prof. E. H., Superintendent of Public Schools, Center and Walnut Sts., Louisville, Ky. (39). 1893. **B**
*Mark, Edward Laurens, Director Zoological Laboratory, Harvard University, Cambridge, Mass. (50). 1901. **F**
Markham, George Dickson, 4961 Berlin Ave., St. Louis, Mo. (50).
Marks, Louis B., 687 Broadway, New York, N. Y. (50).
Marks, William Dennis, C. E., The Art Club, Philadelphia, Pa. (50). **I**
Marlatt, Miss Abby L., Manual Training High School, Providence, R. I. (48).
*Marlatt, Charles L., U. S. Department Agriculture, Washington, D. C. (40). 1895. **F**
Marlow, Frank William, M. D., 200 Highland St., Syracuse, N. Y. (50). **F H I K**
Marple, Charles A., 743 Third Ave., Louisville, Ky. (39). **B**
Marsden, Samuel, 1015 N. Leffengwell Ave., St. Louis, Mo. (27). **A D**

*Marsh, C. Dwight, Ripon, Wis. (34). 1893. **E F**

Marsh, James P., M. D., 1828 5th Ave., Troy, N. Y. (51). **K**

Marshall, Clara, M. D., 1712 Locust St., Philadelphia, Pa. (51). **K**

Marshall, Horace Miller, U. S. Engineer Office, Vicksburg, Miss. (51). **D**

Marsters, Vernon, Indiana University, Bloomington, Ind. (49).

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*Martin, Artemas, Ph. D., LL.D., U. S. Coast and Geodetic Survey, Washington, D. C. (38). 1890. **A**

*Martin, Daniel S., 126 Macon St., Brooklyn, N. Y. (23). 1879. **E F**

Martin, F. W., Ph. D., Analytical and Consulting Chemist, Lynchburg, Va. (49). **C**

Martin, William Lyon, Augusta, Ga. (50). **H**

*Marvin, C. F., U. S. Weather Bureau, Washington, D. C. (39). 1892. **B**

*Marvin, Frank O., Dean School of Engineering, University of Kansas, Lawrence, Kan. (35). 1894. **D**

Marvin, Harry Norton, 841 Broadway, New York, N. Y. (50). **D**

Marvin, Joseph B., M. D., LL.D., President Kentucky University, Louisville, Ky. (51). **I**

Marvin, Walter T., 36 Knox St., Cleveland, Ohio. (50). **H I**

Mason, Amos Lawrence, M. D., Physician to Boston City Hospital, 265 Clarendon St., Boston, Mass. (50). **K**

Mason, Lewis D., M. D., 171 Joralemon St., Brooklyn, N. Y. (51). **K**

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*Mason, Otis T., U. S. National Museum, Washington, D. C. (25). 1877. **H**

*Mason, Dr. William P., Rensselaer Polytechnic Inst., Troy, N. Y. (31). 1886. **C**

Massey, Wilbur Fisk, Botanist and Horticulturist, Agricultural Exper. Station, Raleigh, N. C. (51). **G**

Matas, Rudolph, M. D., Professor of Surgery, Tulane University, New Orleans, La. (50). **H K**

Mateer, Horace N., M. D., Wooster, Ohio. (36). **E F**

*Mathews, John A., Ph. D., Analyst and Consulting Chemist, Columbia University, New York, N. Y. (50). 1902. **C E**

Mathews, Miss Mary Elizabeth, Painesville, Ohio. (41). **F**

Matlack, Charles, "Hidden Hearth," Matunuck, R. I. (27). **I**

Matlack, Ellwood V., Sec'y and Mgr. Laclede Power Co., St. Louis, Mo. (50). **D**

Matthews, Albert, 145 Beacon St., Boston, Mass. (51). **H**

Matthews, Rodolph, D. D. S., 128 N. Main St., Wichita, Kansas. (50). **C F**

*Matthews, Dr. Washington, 1262 N. H. Ave., Washington, D. C. (37). 1888. **H**

Mattison, Fitch, C. E., M. D., Stowell Building, Pasadena, Cal. (51). **K**

Mattoon, A. M., Scott Observatory of Park College, Parkville, Mo. (47). **A**

Maxon, William R., U. S. National Museum, Washington, D. C. (49).

Maxwell, Fred. Baldwin, Ph. D., 308 Franklin Ave., River Forest, Oak Park P. O., Ill. (51). **F**

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Maxwell, Hu., Treasurer Transallegheny Historical Society, Morgantown, W. Va. (50). **E**

*Mayer, Alfred Goldsborough, S. D., M. E., Museum Brooklyn Institute, Eastern Parkway, Brooklyn, N. Y. (47). 1900. **F**

Maynard, George C., 1407 15th St., Washington, D. C. (35). **B D**

Maynard, Washburn, Captain U. S. N., Light House Board, Treasury Department, Washington, D. C. (33). **B**

Mead, Elwood, Consulting Civil Engineer, Washington, D. C. (51). **D**

Means, James, 196 Beacon St., Boston, Mass. (47).

*Mearns, Dr. Edgar A., U. S. A., Fort Adams, Newport, R. I. (49). 1901. **K**

Medsger, Oliver P., Jacob's Creek, Pa. (50). **G**

Meehan, S. Mendelson, Germantown, Philadelphia, Pa. (51). **G**

*Mees, Prof. Carl Leo, Rose Polytechnic Institute, Terre Haute, Ind. (24). 1876. **B C**

*Mell, P. H., Prof. of Geology and Botany, Polytechnic Institute, Auburn, Ala. (39). 1895. **E G**

Mellen, Edwin D., Manufacturer, 1590 Massachusetts Ave., Cambridge, Mass. (51). **D**

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Mellor, Charles C., 319 Fifth Ave., Pittsburg, Pa. (38).

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*Mendenhall, Charles E., Ph. D., University of Wisconsin, Madison, Wis. (48). 1900. **B**

*Mendenhall, T. C., Worcester, Mass. (20). 1874. **B**

Menninger, Charles Frederic, M. D., 1251 Topeka Ave., Topeka, Kan. (50). **F G K**

*Mercer, H. C., Doylestown, Pa. (41). 1893. **H**

Mercer, William Fairfield, Ph. D., Professor of Biology, Ohio University, Athens, Ohio. (50). **F**

*Merriam, Dr. C. Hart, U. S. Department Agriculture, Washington, D. C. (49). 1900. **F**

Merrill, Earle Abbott, 26 Cortlandt St., New York, N. Y. (50).
Merrill, Elmer Drew., U. S. Dept. Agriculture, Washington, D. C. (50). **G**
*MERRILL, FREDERICK J. H., Ph. D., New York State Museum, Albany, N. Y. (35). 1887. **E**
Merrill, Joseph Francis, Ph. D., Professor of Physics and Electrical Engineering, University of Utah, Salt Lake City, Utah. (50). **B D**
Merrill, Lucius Herbert, Professor of Biological Chemistry, University of Maine, Orono, Maine. (50). **C**
Merrill, Payson, 111 Broadway, New York, N. Y. (50).
MERRILL, MRS. WINIFRED EDGERTON, Ph. D., 268 State St., Albany, N. Y. (55). **A**
*Merriman, C. C., 1910 Surf St., Lake View, Chicago, Ill. (29). 1880. **F**
*Merriman, Mansfield, Lehigh University, So. Bethlehem, Pa. (32). 1885. **A D I**
*Merritt, Ernest, Cornell University, Ithaca, N. Y. (33). 1890. **B**
Merrow, Miss Harriet L., Rhode Island College of Agriculture and Mechanic Arts, Kingston, R. I. (44).
Merryweather, George N., 639 Forest Ave., Avondale, Cincinnati, Ohio. (30). **F H**
Mershon, Ralph D., Consulting Enigneer, 621 Broadway, New York, N. Y. (50). **D**
*Metcalf, Maynard M., Ph. D., Professor of Biology, The Woman's College, Baltimore, Md. (50). 1901. **F**
METCALF, ORLANDO, 424 Telephone Building, Pittsburg, Pa. (35). **D**
*Metcalf, William, Pittsburg, Pa. (33). 1894. **D**
Metcalf, Wilmot V., Professor of Chemistry and Physics, Carleton College, Northfield, Minn. (50). **B C**
Metcalfe, Captain Henry, 143 Liberty St., New York, N. Y. (50).
*Metzler, William H., Ph. D., Syracuse University, Syracuse, N. Y. (45). 1899. **A**
Meyer, John Franklin, Professor of Physics and Chemistry in Lower Merion High School, Ardmore, Pa. (51). **B**
*Meyer, Max, Ph. D., Professor of Psychology, University of Missouri, Columbia, Mo. (49). 1901. **H I**
*Mezes, Sidney Edward, Professor of Philosophy, University of Texas, Austin, Texas. (50). 1901. **I**
*Michael, Mrs. Helen Abbott, 35 West Cedar St., Boston, Mass. (33). 1885. **C F**
*Michelson, Prof. A. A., Chicago University, Chicago, Ill. (26). 1879. **B**
Miles, Mrs. Cornelia, Principal of Broadway School, 1544 Franklin St., Denver, Colo. (50). **G**

Miles, Francis T., M. D., 514 Cathedral St., Baltimore, Md. (50). F K

Milham, Willis I., Williams College, Williamstown, Mass. (47). A B

Millar, John M., Escanaba, Mich. (50).

Millard, Charles Sterling, Engineer Maintenance of Way, P. & P. U. Ry., Peoria, Ill. (51). D

Miller, Armand R., Professor of Chemistry, Manual Training High School, Kansas City, Mo. (50). C

*Miller, Prof. Arthur M., State College, Lexington, Ky. (45). 1898. E

Miller, Benjamin LeRoy, Johns Hopkins Univ., Baltimore, Md. (50). E

*Miller, Prof. Dayton C., Case School of Applied Science, Cleveland, Ohio. (44). 1898. B

MILLER, EDGAR G., 213 E. German St., Baltimore, Md. (29). A E F

*Miller, Edmund H., Ph. D., Columbia University, New York, N. Y. (50). 1901. C

*Miller, Ephraim, Professor of Mathematics and Astronomy, State University, Lawrence, Kan. (50). 1901. A

Miller, Prof. Frank E., Otterbein University, Westerville, Ohio. (44). A

Miller, Fred. J., Editor of "American Machinist," 34 Beech St., E. Orange, N. J. (51). D

*Miller, George A., Ph. D., Stanford University, Cal. (46). 1898. A

Miller, George N., M. D., 811 Madison Ave., New York, N. Y. (50). K

Miller, Gerrit S., U. S. Natl. Museum, Washington, D. C. (51). F

Miller, Henry Huntington, Mining and Metallurgical Engineer and Chemist, San Nicholas del Oro, Estado de Guerrero, Mex. (50). C D E

Miller, Herbert Stanley, Electrical Engineer, 1025 East Jersey St., Elizabeth, N. J. (50). D

Miller, Horace George, M. D., 189 Bowen St., Providence, R. I. (51). K

Miller, James Shannon, Professor of Mathematics, Emory and Henry College, Emory, Va. (51). A B

Miller, John A., 2500 Park Ave., Cairo, Ill. (22). D

Miller, John Craig, M. D., Professor of Natural Science, Lincoln University, Pa. (50). B C F K

Miller, Miss Louise Klein, School of Practical Agriculture, Briarcliff Manor, N. Y. (50). I

Miller, P. Schuyler, Mt. Prospect Laboratory, Flatbush Ave., Brooklyn, N. Y. (46). C

Miller, Pleasant T., 816 No. 9th St., Temple, Texas. (50).

*Miller, Prof. William S., University of Wisconsin, Madison, Wis. (42). 1894. F

Millis, John, Major of Engineers, U. S. A., U. S. Engineer's Office, Seattle, Wash. (48). **A B D E**

*Mills, Prof. James, Ontario Agricultural College, Guelph, Ontario, Can. (31). 1895. **C I**

Mills, Samuel C., Newburgh, N. Y. (50). **I**

*Mills, Prof. Wesley, McGill University, Montreal, Can. (31). 1886. **F H**

Mills, William C., Orton Hall, Ohio State University, Columbus, Ohio. (48).

Milne, David, 2030 Walnut St., Philadelphia, Pa. (51).

Minns, Miss S., 14 Louisburg Square, Boston, Mass. (32).

*MINOT, CHARLES SEDGWICK, M. D., Harvard Medical School, Boston, Mass. (28). 1880. **F**

Mitchell, Andrew S., Analytical and Consulting Chemist, State Analyst, 220 Greenbush St., Milwaukee Wis. (51). **C**

Mitchell, Edward, 44 Wall St., New York, N. Y. (50).

Mitchell, Henry Bedinger, Tutor in Mathematics, Columbia University, New York, N. Y. (50). **A**

Mitchell, James, Newburgh, N. Y. (50). **A**

Mitchell, Roland G., 141 Water St., New York, N. Y. (50).

Mitchell, William Francis, M. D., Lancaster, Mo. (51). **K**

Mixer, Chas. Adam, Civil Engineer, Resident Engineer, Rumford Falls Power Co., Rumford Falls, Maine. (51). **D**

Mixer, Fred. K., 427 Delaware Ave., Buffalo, N. Y. (35). **E**

Miyake, Kiichi, Ph. D., Cornell University, Ithaca, N. Y. (51). **G**

Moenkhaus, Wm. J., Bloomington, Ind. (51).

Mohler, John F., 127 S. College St., Carlisle, Pa. (44). **B**

Mohr, Charles, M. D., Professor of Materia Medica and Therapeutics, Hahnemann Medical College and Hospital, Philadelphia, Pa. (51). **K**

Mohr, Louis, M. E., 32 Illinois St., Chicago, Ill. (50). **A D**

*Moler, Geo. S., 106 University Ave., Ithaca, N. Y. (38). 1892.

MOLERA, E. J., Civil Engineer, 606 Clay St., San Francisco, Cal. (50). **D**

Molitor, David, Civil and Consulting Engineer, 125 Park Ave., Fond du Lac, Wis. (51). **C D**

Molitor, Frederic Albert, Little Rock, Ark. (51). **D**

Momsen, Hart, Chief Clerk, Div. of Agric. Census Office, Washington, D. C. (50). **F**

Monfort, Wilson F., Marietta College, Marietta, Ohio. (48). **C**

Monroe, Joseph E., Professor of Physics and Chemistry, Montana State Normal School, Dillon, Mont. (50). **B C**

*Monroe, Will S., State Normal School, Westfield, Mass. (49). 1901. **H**

Montgomery, Edmund, M. D., Hemstead, Texas. (50). **F K**

Montgomery, Edmund B., M. D., 134 North 8th St., Quincy, Ill. (51). **K**

Montgomery, James H., Meadville, Pa. (50).
Moody, Lucius W., New Haven, Conn. (43). **H**
Moody, Mrs. Mary B., M. D., Fair Haven Heights, New Haven, Conn. (25). **E F**
*Moody, Robert O., M. D., Hearst Anatomical Laboratory, San Francisco, Cal. (35). 1892. **F**
Moody, William Albion, Professor of Mathematics, Bowdoin College, Brunswick, Maine. (50). **A**
Moore, Mrs. A. H., Sawyerville, P. Q., Canada. (32). **H**
*Moore, Burton E., University of Nebraska, Lincoln, Neb. (41). 1899. **B**
Moore, Charles James, E. M., P. O. Box 548, Cripple Creek, Colo. (50). **D E**
*Moore, Clarence B., 1321 Locust St., Philadelphia, Pa. (44). 1897. **H**
Moore, Ernest Carroll, Ph. D., Instructor in Philosophy, University of California, Berkeley, Cal. (50). **I**
Moore, Geo. D., Ph. D., 201 Sailsbury St., Worcester, Mass. (40).
*Moore, George Thomas, U. S. Dept. Agriculture, Washington, D. C. (49). 1901. **G**
*Moore, J. W., M. D., Lafayette College, Easton, Pa. (22). 1874. **A B D**
Moore, Philip North, Geologist and Mining Engineer, 121 Laclede Bldg., St. Louis, Mo. (50). **E**
Moore, Robert, Civil Engineer, 61 Vandeventer Place, St. Louis, Mo. (51). **D**
Moore, Stanley H., Manual Training High School, Kansas City, Mo. (50). **A D**
*Moore, Willis L., Chief of the Weather Bureau, U. S. Dept. Agriculture, Washington, D. C. (44). 1897. **B**
*Moorehead, Warren K., Curator of Museum, Phillips Academy, Andover, Mass. (38). 1890. **H**
Morgan, H. A., Professor of Zoology and Entomology, State University, Baton Rouge, La. (50). **F**
Morgan, Wm. F., Short Hills, N. J., (27).
*Morison, George Shattuck, C. E., 49 Wall St., New York, N. Y. (50). 1901. **D**
*Morley, Prof. Edward W., Adelbert College, Cleveland, Ohio. (18). 1876. **B C E**
Morrey, Charles B., Ohio State University, Columbus, Ohio. (48). **F**
Morris, F. W., Villa Nova, Pa. (51).
Morris, Henry L., 16 Exchange Place, New York, N. Y. (49).
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Morris, Robert C., Clerk of Wyoming Supreme Court, Cheyenne, Wyoming. (51). **I**

Morris, Russell Love, Professor of Civil and Mining Engineering, West Virginia State University, Morgantown, W. Va. (50). **D**

Morrison, Gilbert B., 2510 Perry Ave., Kansas City, Mo. (48). **B C I**

Morrison, Thomas, Manager, Edgar Thomson Steel Works, Braddock, Pa. (51). **D**

Morse, Albert P., Wellesley, Mass. (50). **F**

*Morse, E. S., Salem, Mass. (18). 1874. **F H**

Morse, Fred. W., Prof. of Organic Chemistry, New Hampshire College, Durham, N. H. (51). **C**

Morse, Max W., Biological Hall, Ohio State University, Columbus, Ohio. (51). **F**

Morse, Willard S., Apartado "A," Aguascalientes, Mexico, (50). **C D E**

Mortensen, Casper, Box 27, Schenectady, N. Y. (51).

Morton, James F., Andover, N. H. (50).

Moseley, Edwin L., High School, Sandusky, Ohio. (34).

*Moser, Jefferson F., Commander U. S. N., Commanding U. S. S. "Pensacola," Station D, San Francisco, Cal. (28). 1889. **E**

*Moses, Prof. Alfred J., Columbia University, New York, N. Y. (49). 1902. **E**

*Moses, Dr. Thomas F., Worcester Lane, Waltham, Mass. (25). 1883. **F H**

Mosman, Alonzo T., U. S. Coast and Geodetic Survey, Washington, D. C. (51). **D**

*Mottier, David M., Ph. D., Professor of Botany, University of Indiana, Bloomington, Ind. (50). 1901. **F G K**

Motter, Murray Galt, M. D., Medical School, Georgetown University, Washington, D. C. (51). **K**

*Moulton, Forest Ray, Ph. D., Instructor in Celestial Mechanics, University of Chicago, Chicago, Ill. (50). 1901. **A**

Mount, William D., M. E., General Superintendent, Mathieson Alkali Works, Saltville, Va. (51). **D**

Mowry, Wm. A., 17 Riverside Square, Hyde Park, Mass. (29). **I**

Moyer, Harold N., M. D., 103 State St., Chicago, Ill. (51). **K**

Moyer, Lycurgus R., C. E., Montevideo, Minn. (50). **D G**

Muir, John J., Manager, Natl. Steel Casting Co., 345 W. Wayne St., Fort Wayne, Ind. (51). **D**

*Muir, John, Martinez, Cal. (22). 1900. **G**

Mulford, Miss A. Isabel, Missouri Botanical Garden, St. Louis, Mo. (45). **G**

*Mulliken, Samuel P., Mass. Inst. Technology, Boston, Mass. (43). 1899.

Muncaster, Stewart Brown, M. D., 907 Sixteenth St. N.W., Washington, D. C. (51). **K**

Munro, John Cummings, M. D., Instructor in Surgery, Harvard Medical School, Boston, Mass. (50). **F K**

*MUNROE, PROF. C. E., Columbian University, Washington, D. C. (22). 1874. **C**

Munson, T. V., Nurseryman, Denison, Texas. (51). **G**

*Munson, Welton M., Prof. of Horticulture, The University of Maine, Orono, Me. (41). 1899. **F G**

*Munsterberg, Hugo, Harvard University, Cambridge, Mass. (47). 1898.

*Murdoch, John, Public Library, Boston, Mass. (29). 1886. **F H**

Murdock, George J., Mechanician and Inventor, 248 Sixth Ave., Newark, N. J. (50). **A D**

Murray, Charles R., 5636 Washington Ave., Chicago, Ill. (47). **D**

*Murray, Daniel A., Ph. D., Dalhousie College, Halifax, N. S. (47). 1899. **A**

Murray, Robert Drake, M. D., Surgeon Marine Hospital Service, Key West, Fla. (50). **K**

Myer, Mrs. Mary H., 44 Mt. Vernon St., Boston, Mass. (44).

Myers, Edward W., North Carolina Geological Survey, Chapel Hill, N. C. (49).

*Myers, Prof. Geo. W., 6026 Monroe Ave., Chicago, Ill. (46). 1899. **A**

*Myers, William S., M. Sc., F. C. S., Director Nitrate of Soda Propaganda, 12 John St., New York, N. Y. (43). 1898. **C**

Myres, John L., M. A., F. S. A., Christ Church, Oxford, England. (46). **H**

*Nagle, Prof. James C., A. and M. College, College Station, Texas. (40). 1893. **B D**

Nash, Geo. V., Norwood Heights, Williamsbridge, New York, N. Y. (47).

*Nason, Frank L., West Haven, Conn. (36). 1888. **E**

*Needham, James G., Lake Forest College, Lake Forest, Ill. (45). 1898. **F**

*Nef, J. U., University of Chicago, Chicago, Ill. (39). 1891. **C**

Neff, Isaac E., Principal of High School, Kankakee, Ill. (51).

Negley, Henry Hillis, 600 N. Negley Ave., Pittsburg, Pa. (50). **G**

Neiler, Samuel Graham, Consulting and Designing Engineer, 1409 Manhattan Bldg., Chicago, Ill. (50). **D**

Neilson, John, Larchmont, N. Y. (50).

Neilson, Walter Hopper, M. D., Milwaukee, Wis. (51). **K**

Nelson, Aven, Professor of Biology, University of Wyoming, Laramie, Wyoming. (50). **F**

*Nelson, Prof. A. B., Centre College, Danville, Ky. (30). 1882. **A B D**

Nelson, Wm., Rooms 7 and 8, Paterson Natl. Bank, Paterson, N. J. (42).

Nelson, Wolfred, C. M., M. D., F. R. G. S., Astor House, New York, N. Y. (35). **E H**

Nesmith, Henry E., Jr., 28 South St., New York, N. Y. (30). **B C F**
Ness, Helge, Professor of Botany, Agric. & Mech. College, College Station, Texas. (50). **G**
*Newcomb, H. T., Editor of "Railway World," 137 S. 5th St., Philadelphia, Pa. (47). 1898. **I**
*Newcomb, Prof. S., 1620 P St. N.W., Washington, D. C. (13). 1874. **A B**
*Newcombe, Frederick Charles, 1021 E. University Ave., Ann Arbor, Mich. (43). 1896. **G**
Newell, Frank Clarence, 434 Rebecca Ave., Wilkensburg, Pa. (51). **D.**
*Newell, F. H., U. S. Geol. Survey, Washington, D. C. (40). 1893. **E**
*Newell, William Wells, Editor "Journal American Folk Lore," Cambridge, Mass. (41). 1893. **H**
Newson, John F., Stanford University, Cal. (44). **E**
*Newson, Henry Byran, Assistant Professor of Mathematics, University of Kansas, Lawrence, Kansas. (50). 1901. **A**
Nichols, Austin P., 4 Highland Ave., Haverhill, Mass. (37).
*Nichols, Ernest Fox, Dartmouth College, Hanover, N. H. (41). 1893. **B**
*Nichols, E. L., Ph. D., Cornell University, Ithaca, N. Y. (28). 1881. **B C**
Nichols, Othniel Foster, C. E., Principal Assistant Engineer, New East River Bridge, 42 Gates Ave., Brooklyn, N. Y. (51). **D**
Nicola, Frank F., Cor. Wood and Sixth Aves., Pittsburg, Pa. (50). **D**
Niles, Robert Lossing, 66 Broadway, New York, N. Y. (47). **B C D**
*Niles, Wm. H., Mass. Inst. Tech., Boston, Mass. (16). 1874. **E**
*Nipher, Prof. Francis E., Washington University, St. Louis, Mo. (24). 1876. **B**
*Nolan, Edw. J., M. D., Acad. Nat. Sciences, Philadelphia, Pa. (29). 1890. **F**
*Norton, J. B. S., College Park, Md. (47). 1899. **G**
*NORTON, THOMAS H., U. S. Consul, Harput, Turkey in Asia. (35). 1887. **C**
Notestein, F. N., Professor of Mathematics and Physics, Alma College, Alma, Mich. (50). **A B**
Nott, Charles Palmer, Palo Alto, Cal. (50).
*Novy, Dr. Frederick G., Univ. of Michigan, Ann Arbor, Mich. (36). 1889. **C**
*Noyes, Prof. Arthur A., Mass. Inst. Technology, Boston, Mass. (45). 1897. **C**
Noyes, Isaac Pitman, 409 4th St. S.E., Washington, D. C. (49).
*Noyes, Miss Mary Chilton, Ph. D., Lake Erie College, Painesville, Ohio. (43). 1896. **B**

Noyes, Theodore Richards, M. D., Kenwood, N. Y. (51).

*Noyes, Prof. Wm. A., Rose Polytechnic Institute, Terre Haute, Ind. (23). 1885. **C**

Nunn, R. J., M. D., 119 York St., Savannah, Ga. (33). **B H**

*Nuttall, Mrs. Zelia, Peabody Museum, Cambridge, Mass. (35). 1887. **H**

*Nutting, Prof. Charles C., State University of Iowa, Iowa City, Iowa. (40). 1892. **F**

Nylander, Olof O., Box 165, Caribou, Maine. (50). **F**

Oakes, F. James, 58 Stone St., New York, N. Y. (49).

*Oberholser, Harry Church, Div. Biological Survey, U. S. Dept. Agriculture, Washington, D. C. (46). 1898. **E F H**

O'Brien, Matthew Watson, M. D., 908 Cameron St., Alexandria, Va. (51). **K**

Obrig, Adolph, "The Dakota," 1 W. 72d St., New York, N. Y. (50).

O'Connor, Haldeman, 13 North Front St., Harrisburg, Pa. (51). **H**

Oestlund, Oscar W., Entomologist, State University, Minneapolis, Minn. (50). **F**

Offinger, Martin H., M. E., Director Electro-Mech. Dept., Buffalo Commercial and Electro. Mech. Institute, Buffalo, N. Y. (50). **D**

Ogden, Henry Vining, M. D., 141 Wisconsin St., Milwaukee, Wis. (51). **F K**

*Ogden, Herbert G., U. S. C. and G. Survey, Washington, D. C. (38). 1891. **E**

Ogden, Herbert Gouverneur, Jr., M. E., 1610 Riggs Place, Washington, D. C. (50). **B D**

Ogilvie, Miss Ida Helen, Sherman Square Hotel, New York, N. Y. (51). **E**

Oglevee, Christopher S., Instructor in Biology, Lincoln University, Lincoln, Ill. (50). **F**

O'Harra, Prof. Cleophas Cisney, State School of Mines, Rapid City, So. Dak. (49).

Olcott, George M., 86 William St., New York, N. Y. (49).

Oldfield, Anthony M., M. D., Harbor Beach, Mich. (51). **K**

Olive, Edgar W., University Museum, Cambridge, Mass. (48). **G**

Olmsted, John Charles, Landscape Architect, 16 Warren St., Brookline, Mass. (50). **E I**

Olsen, Tinius, Manufacturer, 500 N. 12th St., Philadelphia, Pa. (51). **D**

Oothout, William, Chemist, Metallurgist and Mining Engineer, Santa Barbara, Cal. (50). **C D E**

Opdyke, William S., 20 Nassau St., New York, N. Y. (49).

*Orleman, Miss Daisy M., M. D., Peekskill Military Academy, Peekskill, N. Y. (40). 1897. **F**

*Orleman, Col. Louis H., Ph. D., Principal Peekskill Military Academy, Peekskill, N. Y. (47). 1900.

*Orr, William, Jr., 30 Firglade Ave., Springfield, Mass. (39). 1895. **B F**

Ortmann, Arnold Edward, Ph. D., Curator of Invertebrate Paleontology, Princeton University, 8 Maple St., Princeton, N. J. (51).

*Orton, Edward, Jr., The Normandie, Columbus, Ohio. (48). 1900. **E**

*Orton, W. A., Div. of Veg. Phys. and Path., U. S. Dept. Agriculture, Washington, D. C. (49). **G**

Osborn, Frederick A., Professor of Physics, Olivet Coll., Olivet, Mich. (50). **B**

*Osborn, Henry F., Columbia University, New York, N. Y. (29). 1883. **F**

*Osborn, Herbert, Ohio State University, Columbus, Ohio. (32). 1884. **F**

Osborn, Mrs. W. H., 32 Park Ave., New York, N. Y. (50).

Osborne, Frank Russell, Professor of Physics, John B. Stetson Universty, DeLand, Fla. (50). **B**

Osborne, George Abbott, Professor of Mathematics, Mass. Inst. of Technology, Boston, Mass. (50). **A**

Osborne, Loyall Allen, E. E., Mgr. of Works of Westinghouse Electric and Mfg. Co., Pittsburg, Pa. (50). **D**

Osburn, Raymond Carroll, Professor of Zoology, Fargo College, Fargo, North Dakota. (50). **F**

Osgood, Joseph B. F., Salem, Mass. (31).

Osler, William, M. D., Johns Hopkins University, Baltimore, Md. (51). **F K**

*Osmond, Prof. I. Thornton, State College, Pa. (33). 1889. **A B C**

O'Sullivan, Rev. Denis T., S. J., 761 Harrison St., Boston, Mass. (40). **A B**

Otis, Spencer, 1502 Fisher Building, Chicago, Ill. (51). **D**

*Owen, Charles Lorin, Field Columbian Museum, Chicago, Ill. (50). 1902. **H**

Owen, Prof. D. A., Franklin, Ind. (34). **E**

Owen, Miss Juliette A., 306 N. Ninth St., St. Joseph, Mo. (50). **F**

Owen, Miss Luella Agnes, 306 N. Ninth St., St. Joseph, Mo. (47). **E**

Owen, Miss Mary Alicia, 306 N. Ninth St., St. Joseph, Mo. (50). **H**

Owens, William Gundy, Professor of Chemistry and Physics, Bucknell University, Lewisburg, Pa. (50). **B C**

*Packard, Dr. A. S., 115 Angell St., Providence, R. I. (16). 1875. **E F**

Packard, Frederick A., M. D., 258 So. 18th St., Philadelphia, Pa. (51). **K**

Packard, George Arthur, Metallurgist and Mining Engineer, 18 Lafayette St., Wakefield, Mass. (50). **E**

Packard, John C., 14 Searle Ave., Brookline, Mass. (48). **B**

*Paddock, Wendell, Professor of Botany and Horticulture, Agricultural College, Fort Collins, Colo. (50). 1901. **G**

PAGE, CLARENCE V., Civil and Mining Engineer, P. O. Box 922, Butte, Montana. (51). **D E**

PAGE, DR. DUDLEY L., 46 Merrimack St., Lowell, Mass. (33). **F**

PAGE, MRS. NELLIE K., 46 Merrimack St., Lowell, Mass. (33). **F**

*Paine, Cyrus F., 242 East Ave., Rochester, N. Y. (12). 1874. **A B**

Paine, Robert Treat, President, Associated Charities of Boston, 6 Joy St., Boston, Mass. (50). **I**

Painter, Charles Fairbank, M. D., 372 Mulboro St., Boston, Mass. (50). **F K**

*Palache, Charles, University Museum, Cambridge, Mass. (44). 1896. **E**

*Palmer, Prof. Albert De Forest, Brown University, Providence, R. I. (47). 1900. **B**

*Palmer, Prof. Arthur William, 804 W. Green St., Urbana, Ill. (46). 1898. **C**

*Palmer, Charles Skeele, Ph. D., Professor of Chemistry, University of Colorado, Boulder, Colo. (50). 1901. **C**

Palmer, Dr. Edward, Botanical Div., U. S. Dept. Agriculture, Washington, D. C. (22). **H**

Palmer, Ezra, M. D., 2 Lincoln Hall, Trinity Court, Boston, Mass. (51). **K**

Palmer, Walter Keifer, 411 New York Life Bldg., Kansas City, Mo. (47). **B D**

Paltsits, Victor Hugo, Assistant Librarian, Lenox Library, New York, N. Y. (51).

*Pammel, Prof. L. H., Iowa Agricultural College, Ames, Ia. (39). 1892. **G**

PARISH, HENRY, 52 Wall St., New York, N. Y. (49).

*Park, Roswell, M. D., 510 Delaware Ave., Buffalo, N. Y. (45). 1901. **H K**

Park, William Hallock, M. D., 315 West 76th St., New York, N. Y. (51). **K**

Parker, Miss Florence, 10340 Longwood Ave., Chicago, Ill. (50). **E**

*Parker, George Howard, Assistant Professor of Zoology, Harvard University, Cambridge, Mass. (50). 1901. **F**

*Parker, Herschel C., 21 Fort Greene Place, Brooklyn, N. Y. (43). 1900. **C**

Parker, Horatio N., Biologist to Metropolitan Water Board, 456 Bloomfield Ave., Montclair, N. J. (50). **F**

Parker, J. B., M. D., U. S. N., U. S. Naval Home, Philadelphia, Pa. (50). **K**

Parker, Moses Greeley, M. D., 11 First St., Lowell, Mass. (47). **H**

Parker, Richard Alexander, C. E., E. M., 4 P. O. Square, Boston, Mass. (50). **D E**

Parker, William L., 339 Marlborough St., Boston, Mass. (50).

*PARKHURST, HENRY M., 173 Gates Ave., Brooklyn, N. Y. (23). 1874. **A**

*Parks, C. Wellman, Civil Engineer, U. S. N., Bureau of Navigation, Washington, D. C. (42). 1897.

Parmelee, H. P., 508 Mich. Trust Bldg., Grand Rapids, Mich. (42). **E, H**

Parmly, C. Howard, C. E., Asst. Prof. of Physics, College of the City of New York, N. Y. (50). **B**

Parsell, Henry V. A., 31 E. 21st St., New York, N. Y. (49).

*Parsons, Prof. Charles Lathrop, Durham, N. H. (41). 1896.

Parsons, Mrs. Edwin, 326 W. 90th St., New York, N. Y. (50).

PARSONS, JOHN E., 111 Broadway, New York, N. Y. (36).

Pastorius, Charles Sharpless, Treasurer, Colo. Investment and Realty Co., P. O. Box 428, Colorado Springs, Colo. (51).

Paton, Stewart, M. D., 213 W. Monument St., Baltimore, Md. (50). **K**

Patrick, Frank, 601 Kansas Ave., Topeka, Kansas. (50).

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*Patterson, Harry J., College Park, Md. (36). 1890. **C**

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*Perkins, Prof. Charles Albert, University of Tennessee, Knoxville, Tenn. (47). 1900. **B D**
*Perkins, Prof. George H., Burlington, Vt. (17). 1882. **E F H**
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Petersen, Niels Frederick, Plainview, Neb. (50). **I**
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*Prentiss, Robert W., Professor of Mathematics and Astronomy, Rutgers College, New Brunswick, N. J. (40). 1891. A
*Prescott, Prof. Albert B., Ann Arbor, Mich. (23). 1875. C
Prescott, Samuel Cate, Instructor in Biology, Mass. Inst. Tech., Boston, Mass. (51). K
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*Pulsifer, Wm. H., Nonquitt, Mass. (26). 1879. A H

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Purdue, Albert Homer, Professor of Geology, University of Arkansas, Fayetteville, Ark. (50). E

Purington, Miss Florence, B. S., Mount Holyoke College, South Hadley, Mass. (46). A

Puryear, Chas., Professor of Mathematics, Agric. and Mech. College, College Station, Tex. (51). A

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Randolph, Prof. L. S.. Blacksburg, Va. (33). D
*Rane, Frank Wm., New Hampshire Agric. Exper. Station, Durham, N. H. (42). 1900. G
Rankin, Walter M., Professor of Invertebrate Zoology, Princeton University, Princeton, N. J. (51). F
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Reese, Herbert M., Mt. Hamilton, Cal. (49). B
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Renninger, John S., M. D., Marshall, Minn. (31). C F
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*Richards, Mrs. Robert H., Mass. Institute of Technology, Boston, Mass. (23). 1878. C
*Richards, Prof. Theodore William, Harvard University, Cambridge, Mass. (47). 1899.
Richardson, Alonzo Blair, M. D., Supt. of Government Hospital for Insane, Washington, D. C. (50). K
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Ruland, Frederick D., M. D., Westport, Conn. (51). B C K

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*Runkle, Prof. John D., 15 Everett St., Cambridge, Mass. (2). 1875. A D

Running, Theodore R., Ph. D., Professor of Mathematics and Natural Sciences, St. Olaf College, Northfield, Minn. (50). A

Runyon, William Henry, Teacher of Science, Lyons Township High School, La Grange, Ill. (50). B F

Rupp, August, A. B., College of City of New York, New York, N. Y. (35).

Ruppersberg, Miss Emma A., 842 South High St., Columbus, Ohio. (48). B

*Rusby, Henry H., M. D., 115 West 68th St., New York, N. Y. (36). 1890. G

Russak, Frank, 19 East 65th St., New York, N. Y. (50). I

Russell, A. H., Lieut. Col. U. S. A., Chief Ordnance Officer, Div. of Philippines, Manila, P. I. (38). D

*Russell, Frank, Ph. D., Bureau of American Ethnology, Washington, D. C. (45). 1897. **H**

Russell, Herbert Edwin, Professor of Mathematics, University of Denver, University Park, Colo. (50). **A**

*Russell, Prof. H. L., University of Wisconsin, Madison, Wis. (41). 1894. **G**

*Russell, Israel C., University of Michigan, Ann Arbor, Mich. (25). 1882. **E**

*Russell, James E., Dean of Teachers' College, West 120th St. New York, N. Y. (50). 1901. **H I**

Russell, John B., Superintendent of Schools, Wheaton, Ill. (51). **C**

Russell, Hon. John Edwards, Leicester, Mass. (47). **I**

*Rutter, Frank Roy, Ph. D., U. S. Dept. Agriculture, Washington, D. C. (47). 1900. **I**

*Ryan, Harris J., Cornell University, Ithaca, N. Y. (38). 1890. **B**

*Rydberg, Dr. Per Axel, N. Y. Botanical Garden, Bronx Park, New York, N. Y. (49). 1901. **G**

Rynearson, Edward, Central High School, Pittsburg, Pa. (51). **F G**

Sachs, B., M. D., 21 E. 65th St., New York, N. Y. (49).

Sackett, Miss Eliza D., Cranford, N. J. (35). **F H**

Sackett, Robert L., C. E., Professor of Applied Mathematics and Astronomy, Earlham College, Richmond, Ind. (50). **A**

Sage, John H., Portland, Conn. (23). **F**

Sager, Fred. Anson, Asst. Professor of Physics, University of Illinois, Urbana, Ill. (50). **B**

*St. John, Prof. Charles E., 125 Elm St., Oberlin, Ohio. (46). 1900. **B**

St. John, Howell W., P. O. Box 913, Hartford, Conn. (49). **I**

Salathé Frederick, Ph. D., General Superintendent, Penna. Oil & Gas Co., Casper, Wyoming. (51). **C**

*Salisbury, Prof. R. D., Chicago University, Chicago, Ill. (37). 1890. **B E**

*Salmon, Daniel E., U. S. Dept. Agriculture, Washington, D. C. (31). 1885. **F**

Sander, Dr. Enno, St. Louis, Mo. (27). **C**

Sanderson, E. Dwight, Entomologist, Del. Coll. Agric. Exper. Station, Newark, Del. (50). **F**

Sando, Will J., Manager International Steam Pump Co., 120 Liberty St., New York, N. Y. (51). **E**

Sands, Wm. Hupp, M. D., Fairmont, W. Va. (51). **K**

*Sanford, E. C., Clark University, Worcester, Mass. (49). 1902. **H I**

*Sanford, Fernando, Professor of Physics, Stanford University, Cal. (50). 1901. **B**

Sardeson, Frederick William, Ph. D., Instructor in Geology, University of Minnesota, Minneapolis, Minn. (50). **E**

Sargent, Asa Nathaniel, M. D., 116 Federal St., Salem, Mass. (51). **K**

*Sargent, Dudley Allen, M. D., Director of the Hemenway Gymnasium, Harvard University, Cambridge, Mass. (47). 1899. **H**

Satterfield, David Junkin, D. D., President of Scotia Seminary, Concord, N. C. (50). **I**

Satterlee, F. LeRoy, M. D., 8 W. 18th St., New York, N. Y. (50). **K**

*Saunders, A. P., Ph. D., Hamilton College, Clinton, N. Y. (48). 1900. **C**

*Saunders, Charles E., Ph. D., Experimental Farm, Ottawa, Canada. (41). 1895. **C**

Saunders, Edward W., M. D., 1635 S. Grand Ave., St. Louis, Mo. (51). **K**

Saunders, F. A., Ph. D., Instructor in Physics, Syracuse University, Syracuse, N. Y. (48). **B**

*Saunders, William, LL.D., F. R. S. C., F. L. S., Canadian Experimental Farms, Ottawa, Canada. (17). 1874. **F**

Savage, Dr. W. L., Director of the Gymnasium of Columbia University, Columbia Univ., New York, N. Y. (51).

*Saville, Marshall H., Amer. Mus. Nat. History, Central Park, New York, N. Y. (39). 1892. **H**

Sawyer, Edward, Civil and Mechanical Engineer, Newton, Mass. (51). **D**

Sayre, Miss Clara B., South Bethlehem, Pa. (50). **E H**

*Sayre, Robert H., South Bethlehem, Pa. (28). 1899. **D**

Scaife, Walter B., care A. W. Elford, Catania, Sicily. (49). **I**

Scaife, William Lucien, 28th St., Pittsburg, Pa. (51). **B D**

*SCHAEBERLE, J. M., 502 Second St., Ann Arbor, Mich. (34). 1886. **A**

Schaeffer, Henri N. F., P. O. Box 676, Manchester, N. H. (46). **C**

SCHAFFER, CHAS., M. D., 1309 Arch St., Philadelphia, Pa. (29). **E F**

SCHAFFER, MRS. MARY TOWNSEND SHARPLESS, 1309 Arch St., Philadelphia, Pa. (38). **E F**

*Schaffner, John H., Ohio State Univ., Columbus, Ohio. (48). 1899. **G**

Scharar, Christian H., 2073 N. Main Ave., Scranton, Pa. (33). **A D E H**

Scheffler, Frederick A., Mechanical and Electrical Engineer, Box 233, Glen Ridge, N. J. (50). **D**

Schenck, Charles C., Ph. D., Instructor in Physics, Lehigh University, South Bethlehem, Pa. (51). **B**

SCHERMERHORN, F. AUG., 61 University Place, New York, N. Y. (36).

SCHERMERHORN, WM. C., 49 W. 23d St., New York, N. Y. (36).

Schernikow, Ernest, P. O. Box 1191, New York, N. Y. (49).

Schiaffino, Mariano L., Chief Electrical Engineer, "Campania de Luz de Guadalajara," Belen 2, Apartado 260, Guadalajara, Mexico. (50). D

Schiedt, Richard Conrad, Professor of Biology, Franklin and Marshall College, Lancaster, Pa. (50). F

Schieffelin, Eugene, 865 Madison Ave., New York, N. Y. (50).

Schieren, Hon. Charles A., 405 Clinton Ave., Brooklyn, N. Y. (43). C I

Schiertz, Ferdinand Alfred, Rosario Mines, Ltd., Guadalupe y Calvo, Estado de Chihuahua, Mexico. (50). D E

Schiff, Jacob H., P. O. Box 1193, New York, N. Y. (49).

Schirmer, Gustave, 117 E. 35th St., New York, N. Y. (49).

Schlesinger, Frank, Observer, in charge of International Latitude Observatory, Ukiah, Cal. (51). A

Schlichting, Emil, Analytical Chemist, 646 Broadway, Milwaukee, Wis. (50). C

*Schlotterbeck, Julius O., Ann Arbor, Mich. (46). 1899. G

*Schmeckebier, Lawrence Frederick, Ph. D., U. S. Geol. Survey, Washington, D. C. (50). 1902. E I

Schmid, Dr. H. Ernest, White Plains, N. Y. (25).

Schmitt, A. Emil, M. D., 310 East 57th St., New York, N. Y. (50). K

Schmitt, Ewald, 2235 13th St. N.W., Washington, D. C. (51).

Schobinger, John J, Morgan Park, Ill. (34). B

*Schöney, L., M. D., 143 W. 142d St., New York, N. Y. (29). 1900. F

Schuette, J. H., Green Bay, Wis. (34). B E F

Schultz, Carl H., 430–444 First Ave., bet. 25th and 26th Sts., New York, N. Y. (29).

*Schurman, Jacob Gould, LL.D., President Cornell University, Ithaca, N. Y. (49). 1901.

Schuyler, Philip, Irvington-on-Hudson, N. Y. (49).

Schwalbe, Carl, M. D., 1002 So. Olive St., Los Angeles, Cal. (51). K

*Schwarz, E. A., U. S. Department of Agriculture, Washington, D. C. (29). 1895. F

*Schwatt, Isaac Joachim, Assistant Professor of Mathematics, University of Pennsylvania, Philadelphia, Pa. (51). 1902. A

*Schweitzer, Prof. Paul, State Univ. of Missouri, Columbia, Mo. (24). 1877. B C

Scott, Arthur Curtis, Kingston, R. I. (47).

Scott, Prof. Arthur William, St. David's College, Lampeter, S. Wales, England. (46). A B

*Scott, Charles F., Westinghouse Electric and Mfg. Co., Pittsburg, Pa. (48). 1900. B

Scott, Martin P., M. D., Maryland Agric. College, College Park, Md. (31).

Scott, William, Counsel for Penna. R.R. Co., 450 4th Ave., Pittsburg, Pa. (50). **I**

Scott, W. M., State Entomologist, Atlanta, Ga. (50). **F**

Scovell, M. A., Director and Chemist, Agricultural Experiment Station, Lexington, Ky. (35). **C**

Scripture, Arthur M., Principal of High School, New Hartford, N. Y. (51). **D**

*Scripture, E. W., Yale University, New Haven, Conn. (46). 1901. **H**

*SCUDDER, SAMUEL H., Cambridge, Mass. (13). 1874. **F**

*Scull, Miss Sarah A., Smethport, Pa. (40). 1895. **H**

Seal, Alfred Newlin, Ph. D., Professor of Chemistry, Girard College, Philadelphia, Pa. (50). **B C**

*Seaman, W. H., Chemist, 1424 11th St. N.W., Washington, D. C. (23). 1874. **C F**

Searing, Anna H., M. D., Escondido, Cal. (41). **G**

*Searle, Prof. George M.. St. Thomas College, Catholic University, Washington, D. C. (39). 1891. **A**

Sears, Edward H., Collinsville, Conn. (50). **D I**

Sears, Frederick Edmund, St. Paul's School, Concord, N. H. (47). **C E**

Sears, Henry Francis, Topsfield, Mass. (50).

Seashore, Carl E., Univ. of Iowa, Iowa City, Iowa. (49). **H**

Seawell, Benjamin Lee, Teacher of Biology, State Normal School, Warrensburg, Mo. (50). **F**

Sebert, William F., 48 Strong Place, Brooklyn, N. Y. (41). **A E**

*Sedgwick, William Thompson, Massachusetts Institute of Technology, Boston, Mass. (47). 1898. **F G**

*See, Horace, 1 Broadway, New York, N. Y. (34). 1886. **D**

See, James W., M. E., Opera House, Hamilton, Ohio. (51). **D**

*See, Prof. T. J. J., U. S. Naval Observatory, Washington, D. C. (48). 1901. **A**

*Selby, Augustine Dawson, Agric. Exper. Station, Wooster, Ohio. (44). 1900. **G**

Seligman, Isaac N., Mills Building, New York, N. Y. (49).

Sellers, James Freeman, Prof. of Chemistry, Mercer University, Macon, Ga. (50). **C**

Sellers, William, 1600 Hamilton St., Philadelphia, Pa. (51).

Sercombe, Parker H., Banker, 1a Calle San Francisco, No. 8, City of Mexico, Mexico. (51). **H**

Serrell, Gen. Edward Wellman, C. E., Forest Ave., West New Brighton, N. Y. (50). **B C D**

Sessinghaus, Gustavus, E. M., 1360 Columbine St., Denver, Colo. (50). **E**

Sever, George F., Columbia University, New York, N. Y. (49). **B**

Seymour, A. T., 512 S. 1st Ave., Mt. Vernon, N. Y. (47).

*Seymour, Paul Henry, 215 East 61st St., Chicago, Ill. (44). 1896. **C**

Shafer, John A., Custodian, Carnegie Museum, Pittsburg, Pa. (51). **G**

Shaffner, Samuel C., Supt. Electric Lighting Co., Mobile, Ala. (50). **C D**

Shantz, Homer LeRoy, Colorado Springs, Colo. (50). **F**

Sharp, Charles Cutler, C. E., E. M., President Raven Coal and Coke Co., Boomer, W. Va. (50). **D E**

*Sharp, Dr. Clayton H., Box 114, Newark, N. J. (45). 1897.

Sharpe, Benjamin F., Greenwich, N. Y. (50). **B**

Sharpe, Richard W., Wilmette, Ill. (51). **F**

Sharples, Philip Price, A. B., 22 Concord Ave., Cambridge, Mass. (47). **C**

*Sharples, Stephen P., 13 Broad St., Boston, Mass. (29). 1884. **C**

*SHATTUCK, FREDERICK C., M. D., Professor Clinical Medicine, Harvard Medical College, Boston, Mass. (50). 1901. **F K**

*Shattuck, George Burbank, Johns Hopkins University, Baltimore, Md. (47). 1899. **E**

Shattuck, Samuel Walker, Professor of Mathematics, University of Illinois, Champaign, Ill. (50). **A**

Shaw, Edwin C., M. E., 104 Park St., Akron, Ohio. (50). **D**

Shaw, Henry Clay, C. E., Glenshaw, Pa. (51). **D**

Shaw, Henry Lyman, M. D., 19 Commonwealth Ave., Boston, Mass. (51). **K**

*Shaw, Walter Robert, Ph. D., Prof. of Botany and Entomology, Agric. & Mech. College, Stillwater, Okla. Ter. (47). 1902. **F G**

Shaw, Wilson A., Cashier, Merchants and Manuf. National Bank, Norwood Ave., cor. Forbes Ave., Pittsburg, Pa. (50). **I**

SHEAFER, A. W., Pottsville, Pa. (28).

*Shear, Cornelius L., U. S. Dept. Agriculture, Washington, D. C. (49). 1901. **G**

Shedd, John C., Prof. of Physics, Colorado Springs, Colo. (50). **A B**

Shedd, Solon, Professor of Geology and Mining, Agricultural College, Pullman, Wash. (50). **E**

Sheffield, George St. John, Twin Elms Farm, Attleborough, Mass. (50).

Sheldon, John Lewis, University of Nebraska, Lincoln, Nebraska. (50). **G**

Sheldon, Mrs. J. M. Arms, 18 W. Cedar St., Boston, Mass. (44). **F**

*Sheldon, Samuel, A. M., Ph. D., Polytechnic Institute, Brooklyn, N. Y. (42). 1894. **B**

*Shelton, Edward M., 2728 Boylston Ave., Seattle, Wash. (32). 1892. **F**

SHEPHERD, MISS ELIZABETH, 253 W. 128th St., New York, N. Y. (39).

Shepherd, Frank I., University P. O., Los Angeles, Cal. (48). C
Sheppard, Morris, Lawyer and Actuary, Texarkana, Texas. (51).
Sherman, Franklin, Jr., State Entomologist, Raleigh, N. C. (50). F
Sherman, Lewis, M. D., 448 Jackson St., Milwaukee, Wis. (50). F K
Sherwood-Dunn, B., M. D., 26 Broadway, New York, N. Y. (51). K
Shiland, Andrew, Jr., 262 W. 78th St., New York, N. Y. (50).
*Shimer, Porter W., E. M., Ph. D., Easton, Pa. (38). 1889. C
Shinn, Charles Howard, Inspector of Experiment Stations, University of California, Niles, Cal. (50). F G
Shrader, John Clinton, M. D., LL.D., President Iowa State Board of Health, Iowa City, Iowa. (50). F K
Shropshire, Walter, M. D., Yoakum, Texas. (50). F K
Shultz, Charles S., Hoboken, N. J. (31). F
Shurley, E. L., M. D., 32 Adams Ave., West Detroit, Mich. (51). K
Shute, D. K., M. D., 1101 13th St. N.W., Washington, D. C. (50). F I K
Sickels, I., M. D., 17 Lexington Ave., New York, N. Y. (50). F K
Siemon, Rudolf, 22 East Jefferson St., Fort Wayne, Ind. (40). A F
*Sigsbee, Charles D., Captain U. S. N., Navy Department, Washington, D. C. (28). 1882. D E
Silloway, Perley Milton, Principal of High School, Lewiston, Montana. (51). F
Silvester, Richard W., President Maryland Agricultural College, College Park, Md. (50). G
*Simon, Dr. Wm., 1348 Block St., Baltimore, Md. (29). 1895. C
*Simonds, Prof. Frederic W., University of Texas, Austin, Texas. (25). 1888. E F
Simpson, Friench, Jr., Columbus, Texas. (50). F H K
Simpson, John Crayke, M. D., Govt. Hospital for the Insane, Washington, D. C. (51). K
Singer, George Park, 545 W. Church St., Lock Haven, Pa. (50). B
Sirrine, F. Atwood, 110 New York Ave., Jamaica, N. Y. (44). F
Skeel, Frank D., M. D., 58 East 25th St., New York, N. Y. (50). F K
Skiff, F. J. V., Director, Field Columbian Museum, Chicago, Ill. (43).
*Skinner, Aaron Nichols, U. S. Naval Observatory, Washington, D. C. (40). 1893. A
Skinner, Clarence A., Ph. D., University of Nebraska, Lincoln, Neb. (48). B
Skinner, Clarence Edward, M. D., Physician in charge, The Newhope Hot Air Sanitarium, 67 Grove St., New Haven, Conn. (51). K
*Skinner, Henry, M. D., 716 N. 20th St., Philadelphia, Pa. (47). 1902. F K

Skinner, James Dudley, 823 E. 14th Ave., Denver, Colo. (50). **B D**

Slade, Elisha, Somerset, Mass. (29). **F**

Slagle, Robert Lincoln, Ph. D., President, State School of Mines, Rapid City, S. D. (50). **C E**

Slichter, Charles S., Professor of Applied Mathematics, University of Wisconsin, Madison, Wis. (51). **A**

*Slingerland, Mark Vernon, Assistant Professor of Economic Entomology, Cornell University, Ithaca, N. Y. (50). 1901. **F**

Slocum, Chas. E., M. D., Defiance, Ohio. (34). **F G H**

Slocum, Frederick, Ph. D., Ladd Observatory, Providence, R. I. (47).

Slonaker, James Rollin, University of Chicago, Chicago, Ill. (49). **F**

*Slosson, Edwin E., Professor of Chemistry, University of Wyoming, Laramie, Wyoming. (50). 1901. **C**

Small, John Kunkel, N. Y. Botanical Garden, Bronx Park, New York, N. Y. (44). **G**

Smallwood, Martin, 32 Gorham St., Cambridge, Mass. (50). **E F**

Smillie, Thomas W., U. S. National Museum, Washington, D. C. (40). **F**

*Smith, Alexander, Ph. D., University of Chicago, Chicago, Ill. (40). 1892. **C**

Smith, Allen J., M. D., School of Medicine, University of Texas, Galveston, Tex. (47). **H**

Smith, Mrs. Annie Morrill, 78 Orange St., Brooklyn, N. Y. (49). **G**

Smith, Arthur, 152 Broadway, New York, N. Y. (50). **G**

Smith, Arthur George, Assistant Professor of Mathematics, State University, Iowa City, Iowa. (50). **A**

*Smith, Prof. A. W., Case School of Applied Science, Cleveland, Ohio. (47). 1900. **C**

Smith, Arthur Whitmore, Prof. of Electricity, University of Mississippi, University, Miss. (44). **B**

*Smith, Charles J., 35 Adelbert St., Cleveland, Ohio. (32). 1885. **A B**

*Smith, Prof. Edgar F., University of Pennsylvania, Philadelphia, Pa. (33). 1891. **C**

*Smith, Erastus G., Ph. D., Director Beloit Sanitary Laboratory, Beloit, Wis. (34). 1887. **C**

*Smith, Ernest Ellsworth, 26 East 29th St., New York, N. Y. (43). 1898. **F K**

*Smith, Erwin F., U. S. Dept. Agriculture, Washington, D. C. (34). 1890. **G**

Smith, Eugene, C. E., 317 Washington St., Hoboken, N. J. (50). **D**

*Smith, Prof. Eugene Allen, University, Ala. (20). 1877. **C E**

Smith, E. R., M. D., Toledo, Iowa. (51). **K**

Smith, Felix Ezell, Superintendent of Schools, Victoria, Texas. (51). **F G**

*Smith, Frank, University of Illinois, Urbana, Ill. (49). 1900. **F**
*Smith, Harlan I., Amer. Mus. Nat. History, Central Park, New York, N. Y. (41). 1896. **H**
*Smith, Prof. Harold B., Polytechnic Institute, Worcester, Mass. (43). 1898. **D**
Smith, Harvey F., Attorney at Law, Clarksburg, W. Va. (50). **I**
Smith, Herbert H., Entomologist, Carnegie Institute, Pittsburg, Pa. (51). **F**
Smith, Herbert S. S., Professor of Applied Mechanics, Princeton University, Princeton, N. J. (29). **D**
Smith, Miss J. Angelina, Hopedale, Mass. (45). **E**
Smith, J. C., 131 Carondelet St., New Orleans, La. (48).
Smith, James Hervey, 217 North Central Ave., Chicago, Ill. (40).
*Smith, James Perrin, Ph. D., Asst. Prof. of Paleontology, Stanford University, Cal. (37). 1894. **C E**
*Smith Jared G., Hawaiian Experiment Station, Honolulu, T. H. (47). 1901. **G**
SMITH, MISS JENNIE M., 803 Arch St., Allegheny, Pa. (50). **A F**
*Smith, John B., Ph. D., Rutgers College, New Brunswick, N. J. (32). 1884. **F**
Smith, Joseph R., M. D., LL.D., Colonel and Assistant Surgeon General, U. S. A., 2300 De Lancey St., Philadelphia, Pa. (43).
SMITH, MISS MATILDA H., 803 Arch St., Allegheny, Pa. (50). **A**
Smith, Matthew Mann, M. D., Austin, Texas. (50). **F K**
Smith, Philip Sidney, 20 Trowbridge St., Cambridge, Mass. (47). **E**
*SMITH, Q. CINCINNATUS, M. D., 617 Colorado St., Austin, Texas. (26). 1881. **K**
Smith, Thomas A., Professor of Mathematics and Physics, Beloit College, Beloit, Wis. (50). **A B**
Smith, T. Guilford, Civil Engineer, Regent University, State of New York, Buffalo, N. Y. (50). **D**
*Smith, William Benjamin, Professor of Mathematics, Tulane University, New Orleans, La. (50). 1901. **A**
Smith, Wm. Lincoln, Consulting Electrical and Illuminating Engineer, Concord, Mass. (47). **D**
Smith, William Sidney Tangier, Ph. D., U. S. Geological Survey, Washington, D. C. (50). **E**
Smith, William T., M. D., Prof. of Physiology and Dean of Dartmouth Medical School, Hanover, N. H. (51). **K**
*Smock, Prof. John Conover, State Geologist, Trenton, N. J. (23). 1879. **E**
Smoot, Edgar Kenneth, Engineer and Contractor, 1511 Rhode Island Ave. N.W., Washington, D. C. (51). **D**
Smyth, Bernard Bryan, Librarian and Secretary of the Academy of Science, Topeka, Kansas. (51). **G**

*Smyth, C. H., Jr., Clinton, N. Y. (38). 1894. E

*Sneath, E. Hershey, Professor of Philosophy, Yale University, New Haven, Conn. (51). 1902. H

Snedaker, James Angus, Mining Engineer, 721–722 Equitable Bldg., Denver, Colo. (50). D

Snelling, Charles Mercer, Junior Professor of Mathematics, University of Georgia, Athens, Ga. (50). A

Sneve, Haldor, M. D., Lowry Arcade, St. Paul, Minn. (51). K

Snook, H. Clyde, Professor of Physics and Chemistry, Allegheny College, Meadville, Pa. (50). B C

*Snow, Benjamin W., 518 Wisconsin Ave., Madison, Wis. (35). 1889. B

*Snow, F. H., Professor of Natural History, University of Kansas, Lawrence, Kan. (29). 1881. E F

*Snyder, Prof. Harry, 2090 Dooley Ave., Saint Anthony Park, Minn. (44). 1897. C

Snyder, Miss Lillian, Lafayette, Ind. (47). G

*Snyder, Prof. Monroe B., Philadelphia Astronomical Observatory, Philadelphia, Pa. (24). 1882. A B

Snyder, Nathaniel Marion, Electrical Engineer, Gering, Neb. (50). B D

Snyder, William E., M. E., 510 E. North Ave., Allegheny, Pa. (51). D

Snyder, Zachariah Xenophon, President State Normal School, Greeley, Colo. (50). F

Solotaroff, H., M. D., 251 East Broadway, New York, N. Y. (47). H

Soper, George A., Ph. D., 29 Broadway, New York, N. Y. (46). C

*Soule, R. H., 917 Seventh Ave., New York, N. Y. (33). 1886. D

*Soule, William, Ph. D., Mount Union Coll., Alliance, Ohio. (33). 1899. B C E

Southall, James P. C., Professor of Physics, Alabama Polytechnic Institute, Auburn, Ala. (51). B

Souvielle, Mathieu, M. D., Box 355, Jacksonville, Fla. (36). B E F

Souvielle, Mrs. Mathieu, Box 355, Jacksonville, Fla. (24). A B F

Sowers, David Wood, Supt. Buffalo Branch N. Y. Elec. Veh. Trans. Co., 179 N. Pearl St., Buffalo, N. Y. (51). D

*Spalding, Frederick P., Professor of Civil Engineering, Univ. of Missouri, Columbia, Mo. (46). 1899. D

Spalding, Volney M., Ph. D., Professor of Botany, University of Michigan, Ann Arbor, Mich. (51). G

Spangler, Harry Allen, M. D., Carlisle, Pa. (51). K

Spaulding, Edward G., Ph. D., College of the City of New York, New York, N. Y. (50). I

Spencer, John Campbell, M. D., Medical Department, University of California, San Francisco, Cal. (50). F K

*Spencer, Prof. J. William, 152 Bloor St., Toronto, Canada. (28). 1882. E

*SPENZER, JOHN G., M. D., 116 Rose Bldg., Cleveland, Ohio. (37). 1895. **C**

Sperry, Elmer A., Electrical Engineer, 366–388 Massachusetts Ave., Buffalo, N. Y. (51). **D**

*Speyers, Clarence Livingston, Professor of Physical Chemistry, Rutgers College, New Brunswick, N. J. (50). 1901. **C**

Spicer, Walter E., M. D., 312 West 51st St., New York, N. Y. (51). **K**

Spiegelhalter, Dr. Joseph, 2166 Lafayette Ave., St. Louis, Mo. (47). **E**

*Spinney, L. B., Iowa State College, Ames, Iowa. (42). 1897. **B**

Spofford, Paul N., P. O. Box 1667, New York, N. Y. (36).

Spohn, Arthur Edward, M. D., Corpus Christi, Texas. (50). **F K**

Sprague, C. C., 1900 Locust St., St. Louis, Mo. (50).

SPRAGUE, C. H., Malden, Mass. (29).

*Springer, Dr. Alfred, 312 E. 2d St., Cincinnati, Ohio. (24). 1880. **C**

Springsteen, Harry W., Case School of Applied Science, Cleveland, Ohio. (49). **A B**

Squibb. Charles F., Bernardsville, N. J. (43).

Squibb, Edward Hamilton, M. D., P. O. Box 760, Brooklyn, N. Y. (41). **F K**

.Stackpole, Morrill D., Genl. Supt. Overland Gold Mining Co., Sunshine, Utah. (50). **E**

Stahley, George D., M. D., Gettsyburg, Pa. (47). **F G**

Stanley, William, Great Barrington, Mass. (50).

STANTON, FRANK MCMILLAN, E. M., Agent of Atlantic, Baltic and Central Mining Co's Atlantic Mine, Mich. (51). **D E**

Stanton, John R., 11 and 13 William St., New York, N. Y. (49).

Stanton, Robert Brewster, Civil and Mining Engineer, Sewickley, Pa. (51). **D**

Stanton, Timothy W., Paleontologist, U. S. Geological Survey, Washington, D. C. (50). **E**

Starks, Edwin Chapin, Curator and Instructor, Department of Zoology, Stanford University, Cal. (50). **F**

Starr, Elmer G., M. D., Clinical Prof. of Ophthalmology, University of Buffalo, Buffalo, N. Y. (50). **F K**

*Starr, Frederick, Ph. D., University of Chicago, Chicago, Ill. (36). 1892. **E H**

*Starr, M. Allen, M. D., 5 West 54th St., New York, N. Y. (50). 1901. **K**

Starrett, M. G., 349 W. 85th St., New York, N. Y. (49).

*Stearns, Robert E. C., Ph. D., 1025 East Eighteenth St., Los Angeles, Cal. (18). 1874. **F**

Stearns, Thomas B., Mining Engineer, Denver, Colo. (50). **D E**

Stearns, Theron C., M. D., Consulting Chemist, 44 Montgomery St., Jersey City, N. J. (49).

Stebbins, Miss Fannie A., 480 Union St., Springfield, Mass. (44). **F G**

Steensland, Halbert Severin, M. D., College of Medicine, Syracuse University, Syracuse, N. Y. (50). **F K**

Steer, Justin, M. D., Medical Department, Washington University, St. Louis, Mo. (50). **F K**

*Steiger, George, Chemical Laboratory, U. S. Geol. Survey, Washington, D. C. (40). 1901. **B C E**

Stein, Dr. Simon G., Muscatine, Iowa. (43).

Steinbach, Lewis W., M. D., 1309 N. Broad St., Philadelphia, Pa. (51). **K**

Steiner, Roland, Ph. D., Grovetown, Ga. (48). **H**

*Steinmetz, Charles Proteus, General Electric Co., Schenectady, N. Y. (40). 1895. **B**

Stellwagen, Thos. C., M. D., Prof. Physiology, Philadelphia Dental College, 1328 Chestnut St., Philadelphia, Pa. (51). **K**

Stephens, Henry Matthew, Professor of Biology, Dickinson College, Carlisle, Pa. (50). **F G**

*STEPHENS, W. HUDSON, Lowville, N. Y. (18). 1874. **E H**

Stern, Philip Kossuth, Consulting Mechanical and Electrical Engineer, 130 Fulton St., New York, N. Y. (50). **B D**

Sternberg, Charles Hazelius, Lawrence, Kansas (50). **E F**

*Sternberg, George M., M. D., LL.D., Surgeon-General, U. S. A., War Department, Washington, D. C. (24). 1880. **F**

Sterne, Albert E., M. D., "Norways," Indianapolis, Ind. (51). **K**

Stetson, George R., 1441 Mass. Ave. N.W., Washington, D. C. (49). **H I**

Steuart, Arthur, 951 Equitable Building, Baltimore, Md. (48). **C**

Stevens, Cyrus Lee, M. D., Secy. of the Medical Society of the State of Pa., Athens, Bradford, Co., Pa. (51). **K**

*Stevens, Frank L., Ph. D., Prof. of Biology, College of Agric. and Mech. Arts, West Raleigh, N. C. (44). 1899. **G**

Stevens, Frederick W., Department of Physics, Lake Forest University, Lake Forest, Ill. (50). **B**

Stevens, George T., M. D., 22 East 46th St., New York, N. Y. (28). **B F**

Stevens, James Franklin, M. D., 1136 O St., Lincoln, Neb. (50). **F H K**

*Stevens, James S., Orono, Me. (48). 1900. **B**

*Stevens, Prof. W. LeConte, Washington and Lee University, Lexington, Va. (29). 1882. **B**

Stevenson, Francis L., 79 Lincoln Ave., Chicago, Ill. (47). **D**

*Stevenson, Prof. John J., University Heights, New York, N. Y. (36). 1888. **E**

*Stevenson, Mrs. Matilda C., Bureau of American Ethnology, Washington, D. C. (41). 1893. **H**

Stevenson, Robert, Consulting Civil and Mining Engineer, P. O. Box 2214, San Francisco, Cal. (50). **D E**

Stewart, Douglas, Assistant to Director Carnegie Museum, Pittsburg, Pa. (50). **E**

Stewart, D. D., M. D., 1429 Walnut St., Philadelphia, Pa. (51). **K**

*Stewart, Fred. Carlton, Botanist, N. Y. Agric. Exper. Station, Geneva, N. Y. (44). 1901. **G**

Stewart, J. Clark, M. D., 1628 5th Ave., So. Minneapolis, Minn, (51). **K**

Stewart, James Henry, Director of W. Va. Agric. Exper. Station, Morgantown, W. Va. (50). **E**

*Stewart, Oscar M., Assist. Professor of Physics, University of Missouri, Columbia, Mo. (46). 1900. **B**

Stewart, Ralph Chambers, 1031 Spruce St., Philadelphia, Pa. (51).

Stickney, Gardner P., care Oliver C. Fuller & Co., Milwaukee, Wis. (44). 1901. **H**

*Stieglitz, Dr. Julius, University of Chicago, Chicago, Ill. (39). 1895. **C**

Stieringer, Luther, 129 Greenwich St., New York, N. Y. (50).

*Stiles, Charles W., Ph. D., Dept. of Agric., Washington, D. C. (40). 1892. **F**

Stiles, George M., M. D., Conshohocken, Pa. (51). **K**

Still, George A., 1428 Locust St., Des Moines, Iowa. (50). **C**

Stillhamer, Arthur G., 5809 Jackson Ave., University of Chicago, Chicago, Ill. (50). **B**

Stillman, Prof. John M., Stanford University, California. (41).

Stillwell, Lewis Buckley, Park Row Building, New York, N. Y. (50). **B D**

*Stine, Prof. W. M., Swarthmore College, Swarthmore, Pa. (37). 1900. **A C**

Stingley, Miss Lela Lorena, University of Denver, University Park, Colo. (50). **A**

Stockton, Charles G., M. D., 436 Franklin St., Buffalo, N. Y. (51). **K**

*Stockwell, John N., 1008 Case Ave., Cleveland, Ohio. (18). 1875. **A**

Stoddard, George Howland, M. E., 457 Marlborough St., Boston, Mass. (51). **D**

Stokes, Anson Phelps, 47 Cedar St., New York, N. Y. (50). **I**

*Stokes, Henry Newlin, Ph. D., U. S. Geol. Survey, Washington, D. C. (38). 1891. **C E**

Stone, Alfred H., Greenville, Miss. (51).

Stone, Prof. George E., Mass. Agricultural College, Amherst, Mass. (48). **G**

Stone, Miss Isabelle, Ph. D., Instructor in Physics, Vassar College, Poughkeepsie, N. Y. (50). **B**

Stone, Julius F., Columbus, Ohio. (48).

Stone, Lincoln R., M. D., Newton, Mass. (31).
Stone, Mason A., 161 Broadway, New York, N. Y. (49).
*Stone, Ormond, Director Leander McCormick Observatory, University of Virginia, Charlottesville, Va. (24). 1876. A
Storer, Norman Wilson, care Westinghouse E. & M. Co., Pittsburg, Pa. (50). B
*Story, Prof. Wm. E., Clark University, Worcester, Mass. (29). 1881. A
*Stowell, Prof. T. B., Potsdam, N. Y. (28). 1885. F
*Stradling, George F., Ph. D., 4114 Parkside Ave., Philadelphia, Pa. (41). 1900. B
Strong, Edwin A., Department of Physical Sciences, State Normal School, Ypsilanti, Mich. (46). B
Strong, Frederick F., M. D., 176 Huntington Ave., Boston, Mass. (47). C F
Strong, Frederick G., Box 959, Hartford, Conn. (50). D
*Strong, Wendell M., 32 Nassau St., New York, N. Y. (44). 1899. A B
Stubbert, J. Edward, M. D., 25 E. 45th St., New York, N. Y. (51). K
*Stubbs, W. C., Ph. D., Director, State Experiment Station, Audubon Park, New Orleans, La. (40). 1901. F
Stump, James A., Instructor in Physics, Agricultural College, Fort Collins, Colo. (50). B
*Sturgis, Wm. C., 242 Prospect St., New Haven, Conn. (40). 1892. G
Sullivan, J. A., 308 Main St., Malden, Mass. (27). A
Summers, Henry E., Professor of Zoology, State College, Ames, Iowa. (50). F
Sumner, Francis B., Ph. D., Instructor in Natural History, College of the City of New York. (51). F
Surface, Harvey Adam, Professor of Zoology, Penna. State College, State College, Pa. (50). F
Sutton, Jasper G., M. D., Rushsylvania, Ohio. (48). F K
Sutton, William John, Geologist, Esquimalt and Nanaimo Ry. Co., Victoria, B. C. (50). E
Sutton, W. S., Professor of Science and Art of Education, University of Texas, Austin, Texas. (50). I
Swartzel, Karl D., Department of Mathematics, State University, Columbus, Ohio. (48). A
Sweet, Henry N., 50 Beacon St., Boston, Mass. (40). D H
Swensson, Emil, C. E., 5511 Hays St., Pittsburg, Pa. (51). D
Swezey, Goodwin D., Professor of Astronomy and Meteorology, University of Nebraska, Lincoln, Neb. (50). A
*Swingle, Walter T., U. S. Dept. Agriculture, Washington, D. C. (40). 1892. G

Swope, Gerard, Manager of the Western Electric Co., 810 Spruce St., St. Louis, Mo. (51). B D

TAFT, ELIHU B., Burlington, Vt. (36). H

Taggart, Rush, 319 West 75th St., New York, N. Y. (49).

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Tainter, Frank Stone, Civil Engineer, Far Hills, N. J. (51). D

Talbot, Arthur N., Professor Structural Engineering, University of Illinois, Champaign, Ill. (51). D

*Talbot, Henry P., Mass. Institute of Technology, Boston, Mass. (44). 1896. C

Talbot, Miss Mignon, Teacher of Physical Geography, East High School, 640 Franklin Ave., Columbus, Ohio. (51). E

Talbott, Mrs. Laura Osborne, 1445 Huntington Place, Washington, D. C. (36). F G I

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TALMAGE, JAMES EDWARD, Ph. D., Professor of Geology, University of Utah, Salt Lake City, Utah. (50). E

Tandberg, John P., Instructor in Physics and Chemistry, St. Olaf College, Northfield, Minn. (50). B C

*TANNER, PROF. JOHN HENRY, 7 Central St., Ithaca, N.Y. (47). 1899. A B

*Tarr, Ralph Stockman, Cornell University, Ithaca, N. Y. (49). 1901. E

*Tatlock, John, Jr., 32 Nassau St., New York, N. Y. (50). 1902. A

Taussig, James, Grand Avenue Hotel, St. Louis, Mo. (50). I

*Taylor, Alonzo Englebert, Professor of Pathology, University of California. Residence 1809 Broadway, San Francisco, Cal. (50). 1901. C K

Taylor, Edward B., Pittsburg, Pa. (50). D

Taylor, Edward Randolph, Penn Yan, N. Y. (39). C

*Taylor, Edward Wyllys, M. D., Harvard Medical School, Boston, Mass. (50). 1902. K

*Taylor, Frank B., 391 Fairfield Ave., Fort Wayne, Ind. (39). 1897.

Taylor, Henry L., 60 W. 55th St., New York, N. Y. (49).

Taylor, H. Longstreet, M. D., 75 Lowry Arcade, St. Paul, Minn. (51). K

Taylor, J. Erskine, M. D., Rockland, Pa. (51). K

Taylor, James Landon, M. D., Wheelersburg, Ohio. (51). K I

*Taylor, James M., Colgate University, Hamilton, N. Y. (33). 1901. A D

Taylor, Lewis H., M. D., 83 S. Franklin St., Wilkes-Barre, Pa. (51). K

Taylor, Robert S., Box 2019, Fort Wayne, Ind. (39).

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Teeters, Wilber John, State University, Iowa City, Iowa. (50). **C F K**

Terrell, Arthur Davis, 624 E. Madison St., Iola, Kansas. (51). **C**

*Tesla, Nikola, LL.D., 55 W. 27th St., New York, N. Y. (43). 1895. **B**

Thaw, Benjamin, President Hecla Coke Co., Morewood Place, Pittsburg, Pa. (50). **A D**

† Thaw, Mrs. William, Box 1086, Pittsburg, Pa. (41). **H**

*Thaxter, Roland, Ph. D., Professor of Cryptogamic Botany, Harvard University, Cambridge, Mass. (50). 1901. **G**

Thayer, Harry Stanley, Boulder, Colo. (50). **C**

Theisen, Clement F., M. D., 172 Washington Ave., Albany, N. Y. (51). **K**

Thelberg, Elizabeth B., M. D., Resident Physician and Professor of Physiology and Hygiene, Vassar College, Poughkeepsie, N. Y. (50). **F K**

Thiemann, Hermann, Manchester, Mass. (50). **G**

*Thom, Charles, Instructor in Botany, University of Missouri, Columbia, Mo. (50). 1901. **G**

*Thomas, Benjamin F., Professor of Physics, State University, Columbus, Ohio. (29). 1882. **A B**

Thomas, George T., M. D., Rogers, Texas. (50). **F K**

Thomas, Jerome B., Captain and Assistant Surgeon, U. S. V., care Chief Surgeon, Manila, P. I. (51). **K**

*Thomas, Prof. M. B., Crawfordsville, Ind. (41). 1894. **G**

Thompson, Alton H., 721 Kansas Ave., Topeka, Kan. (33). **H**

Thompson, Miss Anna F., P. O. Box 32, Summit, N. J. (49).

Thompson, Hugh L., Consulting Mechanical Engineer, Waterbury, Conn. (51). **D**

Thompson, James E., New Carlisle, Ohio. (48).

Thompson, James Edwin, 3224 Broadway, Galveston, Texas. (50).

Thompson, J. L., M. D., 22 West Ohio St., Indianapolis, Ind. (39). **F**

*Thompson, Joseph Osgood, Amherst, Mass. (41). 1893.

Thompson, Robert M., 99 John St., New York, N. Y. (49).

Thompson, Rev. Walter, D. D., Garrison-on-Hudson, N. Y. (49).

Thompson, William, Mining, Metallurgical and Mechanical Engineer, Rossland Great Western Mines, Ltd., Rossland, B. C. (50). **D E**

Thompson, W. Gilman, M. D., 34 E. 31st St., New York, N. Y. (50). **F K**

*Thomson, Elihu, Swampscott, Mass. (37). 1888. **B**

*Thomson, Wm., M. D., 1426 Walnut St., Philadelphia, Pa. (33). 1885. **B**

Thornber, John J., Botanist, Agr. Exper. Station, Tucson, Arizona. (50). G
*Thornburg, Charles L., Lehigh Univ., S. Bethlehem, Pa. (44). 1897. A
*Thorndike, E. L., Ph. D., Adjunct Prof. of Genetic Psychology, Columbia Univ., New York, N. Y. (49). 1901. H I K
THORNE, MRS. PHOEBE ANNA, 558 Madison Ave., New York, N. Y. (50).
Thorne, Samuel, Jr., 55 Liberty St., New York, N. Y. (49).
*Thruston, Gates Phillips, Nashville, Tenn. (38). 1890. H
*Thruston, R. C. Ballard, Ballard & Ballard Co., Louisville, Ky. (36). 1896. E
*Thurston, Prof. R. H., Sibley College, Cornell University, Ithaca, N. Y. (23). 1875. D
Tibbals, George Attwater, 148 Milton St., Brookyn, N. Y. (51).
Tiffany, L. C., 27 E. 72d St., New York, N. Y. (50).
*Tight, Prof. William George, Albuquerque, N. M. (39). 1900. E
Tilley, Charles Edward, Teacher of Physics and Chemistry, Hope Street High School, Providence, R. I. (50). B C
Tilson, P. S., Associate Professor of Chemistry, A. and M. College, College Station, Tex. (50). C
Tilton, John Littlefield, Simpson College, Indianola, Iowa. (50). E
Tingle, J. Bishop, Illinois College, Jacksonville, Ill. (50). C
*Titchener, E. B., Professor of Psychology, Cornell University, Ithaca, N. Y. (51). 1902. K
*Tittmann, Otto H., Supt. U. S. C. and G. Survey, Washington, D. C. (24). 1888. A
Titus, E., Jr., 10 E. 70th St., New York, N. Y. (50).
Titus, E. S. G., Natural Nistory Bldg., University of Illinois, Urbana, Ill. (50). F
Todd, Albert M., Kalamazoo, Mich. (37). C
*Todd, Prof. David P., Director Lawrence Observatory, Amherst, College, Amherst, Mass. (27). 1881. A B D
*Todd, Prof. James E., State Univ., Vermilion, S. Dak. (22). 1886. E F
Todd, J. H., M. D., Christmas Knoll, Wooster, Ohio. (48).
Todd, William J., M. D., Mt. Washington, Baltimore, Md. (51). K
Tolman, Rev. Marcus Alden, 123 S. High St., Bethlehem, Pa. (50). I
Tompkins, Stonewall, M. E., 1602 McKinney Ave., Houston, Tex. (51). D
Tonnele, Theodore, Metallurgical Engineer, 919 College Ave., Pittsburg, Pa. (50). E
*Tooker, William Wallace, Sag Harbor, N. Y. (43). 1895. H
Toothe, William, Madison, N. J. (49).
Totman, David M., M. D., 303 Montgomery St., Syracuse, N. Y. (50). K

Tower, Olin F., Ph. D., Instructor in Chemistry, Adelbert College, Cleveland, Ohio. (50). **C**

*Towle, William Mason, State College, Pa. (44). 1902. **B**

*Townsend, Charles O., U. S. Dept. Agriculture, Washington, D. C. (46). 1902. **G**

Townson, Andrew J., President Board of Education, Granite Building, Rochester, N. Y. (50). **I**

Tracy, Edward A., M. D., 353 Broadway, S. Boston, Mass. (51). **K**

*Tracy, Samuel M., Biloxi, Miss. (27). 1881. **G**

*Traphagen, Frank W., Ph. D., Bozeman, Montana. (35). 1889. **C E F**

Trask, Spencer, 27 Pine St., New York, N. Y. (50). **I**

Traylor, Miss Mary Clark, 653 S. Grant Ave., Denver, Colo. (50). **A**

Treat, Erastus B., 241–243 W. 23d St., New York, N. Y. (29). **F I**

*Trelease, Wm., Ph. D., Director Missouri Botanical Gardens, St. Louis, Mo. (39). 1891. **G**

Trimble, Robert E., Asst. Meteorologist and Irrigation Engineer, Agricultural College, Fort Collins, Colo. (50). **B E**

Troth, Alonzo P., Principal of High School, Leadville, Colo. (50). **F**

*Trowbridge, Augustus, Ph. D., Dept. Physics, University of Wisconsin, Madison, Wis. (47). 1900. **B**

*Trowbridge, Charles Christopher, Tutor in Physics, Columbia University, New York, N. Y. (50). 1901. **B**

Trowbridge, Luther H., 13 Madison Ave., Detroit, Mich. (29).

Trowbridge, Mrs. M. E. D., 13 Madison Ave., Detroit, Mich. (21). **G I**

*True, Fred. W., U. S. National Museum, Washington, D. C. (28). 1882. **F**

*True, Rodney Howard, U. S. Dept. Agriculture, Washington, D. C. (46). 1899. **G**

Trueblood, Mary Esther, 9 Crawford St., Boston, Mass. (47). **A**

Truesdell, George, Room 22, Wyatt Building, Washington, D. C. (49). **I**

Tucker, Richard Hawley, C. E., Astronomer, Lick Observatory, Mt. Hamilton, Cal. (50). **A D**

Tucker, William Albert, New Rockford, N. Dak. (51). **G**

Tucker, William Conquest, Civil and Sanitary Engineer, 156 Fifth Ave., New York, N. Y. (51). **D**

*Tucker, Willis G., M. D., Albany Medical College, Albany, N. Y. (29). 1888. **C**

*TUCKERMAN, ALFRED, Ph. D., 342 W. 57th St., New York, N. Y. (39). 1891. **C**

Tuckerman, Louis Bryant, Jr., Box 1096, Station A, Lincoln, Neb. (50). **A B**

*Tufts, Frank Leo, Ph. D., Tutor in Physics, Columbia University, New York, N. Y. (50). 1901. **B**

Tuohy, John, Tulare, California. (50). B I
Turck, Fenton B., M. D., 362 Dearborn Ave., Chicago, Ill. (51). K
Turnbull, Thomas, Jr., M. D., Asst. Professor of Practice of Medicine, Allegheny University, Allegheny, Pa. (50). F K
Turner, Archelaus E., President Waynesburg College, Waynesburg, Pa. (50). E I
Turner, J. Spencer, 70 Worth St., New York, N. Y. (43). B
*Tuttle, Prof. Albert H., University of Virginia, Charlottesville, Va. (17). 1874. F
Tweedy, Miss Alice B., Spuyten Duyvil, New York, N. Y. (49).
*Twitchell, E., Wyoming, Ohio. (39). 1891. C
Tyler, Prof. H. W., 491 Boylston St., Boston, Mass. (51).
Tyler, Ansel Augustus, Ph. D., Professor of Science, Bellevue College, Bellevue, Neb. (50).
Tyrrell, Joseph Burr, Mining Engineer, Dawson, Y. T., Canada. (50). D E
Tyson, James, M. D., 1506 Spruce St., Philadelphia, Pa. (51). K
*Uhler, Philip R., 254 W. Hoffman St., Baltimore, Md. (19). 1874. E F
Uihlein, August, 332 Galena St., Milwaukee, Wis. (51).
*Underwood, Lucien M., Columbia University, New York, N. Y. (23). 1885. G
Underwood, William Lyman, Lecturer on Biology, Mass. Institute of Technology, Boston, Mass. (51). F K
*Updegraff, Milton, U. S. Naval Observatory, Washington, D. C. (40). 1895. A
*Upham, Warren, Secy. Minnesota Historical Society, St. Paul, Minn. (25). 1880. E
Upton, George B., Milton, Mass. (50).
*Upton, Winslow, Ladd Observatory, Providence, R. I. (29). 1883. A
Vail, Miss Anna Murray, 29 Washington Square, New York, N. Y. (50).
Vaile, Joel F., 420 Equitable Building, Denver, Colo. (50). I
Valentine, Edw. P., Richmond, Va. (33). H
Vallé, Jules F., M. D., 3303 Washington Ave., St. Louis, Mo. (51). K
*Van Amringe, John Howard, Professor of Mathematics, Columbia University, New York, N. Y. (50). 1901. A
Van Antwerp, Rev. Francis J., 26 Harper Ave., Detroit, Mich. (46).
VAN BEUREN, FREDERICK T., 21 W. 14th St., New York, N. Y. (36).
Van Brunt, Cornelius, 319 E. 57th St., New York, N. Y. (28).
Vanderbilt, Cornelius, 602 Fifth Ave., New York, N. Y. (51). D
[Vanderlaan, J., M. D., 200 S. Terrace St., Muskegon, Mich. (51). K

Vanderpoel, Frank, M. D., 153 Center St., Orange, N. J. (50). F K

Van Dine, Delos Lewis, Honolulu Normal School, Honolulu, T. H. (51).

Van Duyn, John, M. D., 318 James St., Syracuse, N. Y. (50). F K

*Van Dyck, Prof. Francis Cuyler, P. O. Box 224, New Brunswick, N. J. (28). 1882. B C F

Van Dyck, William Van Bergen, Cronly, N. C. (50). D

Van Gelder, Arthur P., Landing, N. J. (50).

Van Giesen, Ira, 1 Madison Ave., New York, N. Y. (49).

Van Gundy, M. C., Herron Hill Laboratory, Center Ave. and Craig St., Pittsburg, Pa. (51). C

*Van Hise, Charles R., Univ. of Wisconsin, Madison, Wis. (37). 1890. E

Van Ingen, Dr. Gilbert, Columbia University, New York, N. Y. (49).

Van Orden, Charles H., Civil Engineer, Catskill, N. Y. (51). D

Van Ornum, Prof. John Lane, Professor of Civil Engineering, Washington University, St. Louis, Mo. (50). D

Vansize, William B., 253 Broadway, New York, N. Y. (50). D

*Van Slyke, Lucius L., Agr, Exper. Station, Geneva, N. Y. (41). 1901. C

Van Valkenburg, Hermon L., Electrical Engineer, Amber Club, Shady Ave., Pittsburg, Pa. (51). B

*Van Vleck, Prof. John M., Wesleyan University, Middletown, Conn. (23). 1875. A

Van Winkle, Edgar B., 115 E. 70th St., New York, N.Y. (49).

Varney, A. L., Major of Ordnance, U. S. A., San Antonio Arsenal, San Antonio, Texas. (44). H

VAUX, GEORGE, JR., 404 Girard Building, Philadelphia, Pa. (33). A E

Veblen, Andrew A., Professor of Physics, State University, Iowa City, Iowa. (50). B

Veeder, Curtis Hussey, Mechanical Engineer, 40 Willard St., Hartford, Conn. (50). B D

Velsor, Joseph A., 105 McDonough St., Brooklyn, N. Y. (50). C

*Venable, Prof. F. P., Chapel Hill, N. C. (39). 1891. C

Venable, Wm. Mayo, C. E., E. E., care Natl. Contracting Co., 11 Broadway. New York, N. Y. (50). D

*Verrill, Prof. A. E., New Haven, Conn. (47). 1891. F

Vest, Solomon Alexander, Assistant Chemist, Navassa Guano Co., Wilmington, N. C. (51). C

Villard, Mrs. Henry, 145 W. 58th St., New York, N. Y. (36).

Vinal, W. Irving, 1106 East Capitol St., Washington, D. C. (40). E

Vineberg, Hiram N., M. D., 751 Madison Ave., New York, N. Y. (51). K

*Vining, E. P., 49 Second St., San Francisco, Cal. (32). 1887. H

*Vogdes, A. W., Major, 5th Artillery, U. S. A., San Diego, Cal. (32). 1885. **E F**

Voje, John Henry, M. D., Private Sanatorium Waldheim, Oconomowoc, Wis. (51). **K**

von Herrmann, C. F., Section Dir. U. S. Weather Bureau, Raleigh, N. C. (51). **B**

von Ihering, F., Museu Paulista, Sao Paulo, Brazil. (51).

von Mansfelde, Alexander S., M. D., "Quality Hill," Ashland, Neb. (50). **F G H K**

*von Nardroff, Ernest R., 360a Tompkins Ave., Brooklyn, N. Y. (44). 1896. **B**

von Ruck, Karl, M. D., Director, Winyah Sanitarium, Asheville, N. C. (51). **K**

*von Schrenk, Hermann, Shaw School of Botany, St. Louis, Mo. (49). 1901. **G**

*Voorhees, Louis A., P. O. Box 290, New Brunswick, N. J. (43). 1895. **C**

Voris, Floyd Thomas, Professor of Natural Science, Buena Vista College, Storm Lake, Iowa. (50). **B**

Votey, J. William, Professor of Civil Engineering, University of Vermont, Burlington, Vt. (50). **D**

Vreeland, Frederick K., E. E., Box 1877, New York, N. Y. (50). **B D G**

Waddell, Montgomery, 135 Broadway, New York, N. Y. (51). **D**

Wade, John W., M. D., 318 N. Second St., Millville, N. J. (51). **K**

Wadman, W. E., 102 Lord Ave., Bayonne, N. J. (50).

*Wadsworth, M. Edw., Professor of Mining and Geology, Penna. State Coll., State College, Pa. (23). 1874. **E**

Wadsworth, William Austin, Genesee, Livingston, Co., N. Y. (50). **G**

*Wagner, Frank C., Rose Polytechnic Institute, Terre Haute, Ind. (34). 1897. **D**

Wagner, George, 1915 Niles Ave., St. Joseph, Mich. (46). **F G**

Wagner, Samuel, President of Wagner Free Institute of Science, Franklin Building, 133 S. 12th St., Philadelphia, Pa. (51).

Wainwright, Jacob T., Metallurgical Engineer, P. O. Box 774, Chicago, Ill. (51). **D E**

Wainwright, John William, M. D., 177 W. 83d St., New York, N. Y. (51). **K**

Waite, Frederick Clayton, Ph. D., Asst. Prof. of Histology and Embryology, Medical Department, Western Reserve Univ., Cleveland, Ohio. (50). **F K**

Waite, M. B., U. S. Dept. Agriculture, Washington, D. C. (37). **G**

*Walcott, Charles D., Director U. S. Geol. Survey, Washington, D. C. (25). 1882. **E F**

*Waldo, Prof. Clarence A., Purdue Universty, Lafayette, Ind. (37). 1889. **A**

*Waldo, Leonard, 520 Stelle Ave., Plainfield, N. J. (28). 1880. A
Wales, Charles M., M. E., 11 Broadway, New York, N. Y. (51). D
Wales, Salem H., 25 E. 55th St., New York, N. Y. (36).
Walker, Byron Edmund, Toronto, Can. (38). E
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*Ward, Prof. Henry B., University of Nebraska, Lincoln, Neb. (48). 1899. F
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*Ward, Robert De C., Harvard Univ., Cambridge, Mass. (47). 1902 E.
*Ward, Dr. R. H., 53 Fourth St., Troy, N. Y. (17). 1874. F G
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*Ware, Wm. R., School of Architecture, Columbia University, New York, N. Y. (36). 1901. D

*WARINGTON, ROBERT, F. R. S., Rothamsted, Harpenden, England. (40). 1899. C

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*Warren, Prof. Howard C., Princeton Univ., Princeton, N. J. (46). 1901. H K

*Warren, Joseph W., M. D., Bryn Mawr. Pa. (31). 1886. F

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*Washington, Dr. Henry S., Locust, N. J. (44). 1897. E

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*WATSON, PROF. WM., 107 Marlborough St., Boston, Mass. (12). 1884. A

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*Weber, Prof. Henry A., Ohio State Univ., Columbus, Ohio. (35). 1888. **C**

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*Webster, Prof. F. M., Agric. Exper. Station, Wooster, Ohio. (35). 1890. **F**

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*White, David, U. S. Geol. Survey, Washington, D. C. (40). 1892. **E F**

*White, Horace, Editor "New York Evening Post," 18 W. 69th St., New York, N. Y. (50). 1901. **I**

*White, H. C., Ph. D., University of Georgia, Athens, Ga. (29). 1885. **C**

*WHITE, PROF. I. C., State Geologist of West Virginia, Morgantown, W. Va. (25). 1882. **E**

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*Whitman, Prof. Frank P., Adelbert College, Cleveland, Ohio. (33). 1885. **A B**

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*Willis, Bailey, U. S. Geological Survey, Washington, D. C. (36). 1890. E

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Williston, Dr. Samuel W., University of Kansas, Lawrence, Kansas. (51). F K

*Willoughby, Charles C., Peabody Museum, Cambridge, Mass. (45). 1897. H

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*Willson, Prof. Frederick N., Princeton, N. J. (33). 1887. **A D**

*Wilson, Henry Van Peters, Professor of Biology, University of North Carolina, Chapel Hill, N. C. (50). 1901. **F**

Wilson, John C., Cosmos Club, Washington, D. C. (49). **I**

*Wilson, Joseph Miller, Room 1030, Drexel Building, Philadelphia, Pa. (33). 1886. **D**

Willson, Mortimer, M. D., Port Huron, Mich. (50). **A F**

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*Wilson, Robert N., Macleod, Alberta, Canada. (42). 1895. **H**

*Willson, Robert W., Cambridge, Mass. (30). 1890. **A B**

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*Withers, Prof. W. A., A. and M. College, Raleigh, N. C. (33). 1891. **C**

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CHARLESTOWN.

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Flanders, Charles S.

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GREENFIELD.

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GROTON.

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LEICESTER.

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Kendrick, Arthur.
Sawyer, Edward.
Stone, Lincoln R.
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SALEM.

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Sears, Henry Francis.

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Ballard, C. A.

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Leathers, W. S.
Smith, Arthur W.

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MISSOURI.

CARTERSVILLE.

Fisher, William Bowditch.

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KANSAS CITY.

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MEXICO.

Baskett, James Newton.

PARKVILLE.

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SPRINGFIELD.

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WARRENSBURG.

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BUTTE.

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ASHLAND.

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CALLAWAY.

Bates, John Mallery.

COLUMBUS.

Kern, Walter McCullough.

GERING.

Snyder, Nathaniel Marion.

HEBRON.

Wilson, Andrew G.

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Peterson, Niels Frederick.

WAHOO.

Bush, John C. F.

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RENO.

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TYBO.

Redding, Allen C.

NEW HAMPSHIRE.

ANDOVER.

Eastman, J. R.
Morton, James F.

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Steeple Rock.

Robinson, Sanford.

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Gause, Fred. Taylor.

MEXICO.

AGUASCALIENTES.

Morse, Willard S.

CITY OF MEXICO.

de Arozarena, Rafael M., 2 da Calle de las Estaciones.
Hard, James M. B., Cordobanes 16.
Sercombe, Parker H., 1a Calle San Francisco No. 8.

COLIMA.

Herbert, Arthur P.

CORDOBA.

Bowman, Joseph H.

DURANGO.

Carnaghan, Edward D.

GUADALAJARA.

Schiaffino, Mariano L.

GUADALUPE Y CALVO.

Schiertz, Ferdinand A.

JALAPA.

Gutierrez, Manuel R.

LINARES.

McLimont, Andrew W.

MONTEREY.

Dysterud, E.

ORIZABA.

Barnett, Robert C.

PACHUCA.

De Landero, Carlos F.

SALTILLO.

Burton, Standish B.

SAN JOSE DE GRACIA.

Tays, Eugene A. H., Anglo-Mexican Mining Company.

SAN NICOLAS DEL ORO.

Miller, Henry Huntington.

SOMBRERETE.

McMahan, Charles Hays.

TORRES.

Peterson, Bertel.

NICARAGUA.

LEON.

Crawford, John.

SICILY.

CATANIA.

Scaife, Walter B., care A. W. Elford.

SOUTH AFRICA.

CAPE TOWN.

Mally, Charles William, Department of Agriculture.

TURKEY.

HARPUT.

Norton, Thomas H., United States Consulate.

DECEASED MEMBERS.

[A list of deceased members of the Association, so far as known at the time of publishing the volume of Proceedings of the Springfield meeting, May, 1896, is given in that volume. At the Buffalo meeting the Council directed the Permanent Secretary to omit the printing of the full list of deceased members in the annual volumes and to print only the additions to the list. Since the publication of the list printed in the Denver Proceedings (Vol. 50) notices have been received of the decease of the following members.]

Goff, E. S., Madison, Wis. (35). Died June 6, 1902.

Hyatt, Alpheus, Natural History Society, Boston, Mass. (18). Born April 5, 1838. Died January 15, 1902.

Johnson, John B., Madison, Wis. (33). Died June 23, 1902.

Lacoe, Ralph D., 35 Exeter St., Pittston, Pa. (31).

Morton, H., Stevens Institute of Technology, Hoboken, N. J. (18).

ROBERTSON, THOMAS D., Rockford, Ill. (10). Born March 4, 1818. Died February 5, 1902.

Smith, J. Barry, S. J., Georgetown University, Washington, D. C. (50). Died September, 1901.

Smith, Miss Sara Winthrop, Nantucket, Mass. (50). Died January 2, 1902.

SMITH, USELMA C., 1515 Green St., Philadelphia, Pa. (33). Born June 9, 1841. Died May 2, 1902.

Stevens, Edwin A., Victor, Colo. (50). Died January, 1902.

Wilson, Thomas, LL.D., U. S. National Museum, Washington, D. C. (36). Died May 4, 1902.

Wright, Rufus, 19 N. May St., Chicago, Ill. (37). Died April, 1900.

ADDRESS

BY

CHARLES SEDGWICK MINOT,

THE RETIRING PRESIDENT OF THE ASSOCIATION.

THE PROBLEM OF CONSCIOUSNESS IN ITS BIOLOGICAL ASPECTS.

Our Association meets in Pittsburg for the first time. We are glad to indicate by our assembling here our appreciation of the immense work for the promotion of education and science which has begun in this city and already is of national value. It has been initiated with so great wisdom and zeal that we expect it to render services to knowledge of the highest character, and we are glad to be guests of a city and of institutions which are contributing so nobly to the cause of science.

We may congratulate ourselves on the bright prospects of the Association. Our membership has grown rapidly, and ought soon to exceed four thousand. Every member should endeavor to secure new adherents. For our next meeting we are to break with the long tradition of summer gatherings, and assemble instead at New Year's time, presumably at Washington. To render this possible it was necessary to secure the co-operation of our universities, colleges, and technical schools to set aside the week in which the first of January falls, as *Convocation Week* for the meeting of learned societies. The plan, owing to the cordial and almost universal support given by the higher educational institutions, has been successfully carried through. For the winter meetings we have further succeeded in securing the co-operation of numerous national societies. The change in our time of meeting is an experiment which we venture upon with

the greater confidence, because of the success of our present meeting in Pittsburg.

For my address this evening I have chosen the theme: "The Problem of Consciousness in its Biological Aspects." I hope both to convince you that the time has come to take up consciousness as a strictly biological problem, and also to indicate the nature of that problem, and some of the actual opportunities for investigating it. It is necessary to begin with a few words on the philosophical interpretation. We shall then describe the function of consciousness in animal life, and consider its part in the evolution of animals and of man. The views to be stated suggest certain practical recommendations, after presenting which I shall conclude by offering an hypothesis of the relation of consciousness to matter and force.

Consciousness is at once the oldest problem of philosophy and one of the youngest problems of science. The time is not yet for giving a satisfactory definition of consciousness, and we must fain content ourselves with the decision of the metaphysician, who postulates consciousness as an ultimate datum or concept of thought, making the brief dictum *cogito, ergo sum* the pivot about which his system revolves. I have endeavored vainly to discover by reading and by questioning those philosophers and psychologists whom I know, some deeper analysis of consciousness, if possible, resolving it into something more ultimate.

Opinions concerning consciousness are many and often so diverse as to be mutually exclusive, but they may be divided into two principal classes. The first class includes all those views which make of consciousness a real phenomenon; the second, those views which interpret it as an epiphenomenon. We are, I think practically all, agreed that the fundamental question is: Does or does not consciousness affect directly the course of events?—or, stated in other words, is consciousness a true cause? In short, we encounter at the outset the problem of free-will; of which more later.

The opinion that consciousness is an epiphenomenon has gained renewed prominence in recent times, for it is, so to

speak, a collateral result of that great movement of European thought which has culminated in the development of the doctrine of monism. Monism itself is postulated chiefly upon the two greatest discoveries of the nineteenth century—the law of the conservation of energy, and the law of the evolution of species. Both laws establish a greater unity in the phenomena of the universe than mankind had previously been able to accept. In the physical world, instead of many forces, we now recognize only one force, which assumes various forms of energy; and in the living world we recognize one life, which manifests itself in many types of form. With these two unities in mind, what could be nearer than the thought that the unity goes still deeper, and that the phenomena of the inanimate or physical, and of the living world are fundamentally identical? The progress of physiological science has greatly increased the impetus towards the adoption of this thought as the cardinal dogma of the new faith, because the work of physiologists has been so devoted to the physical and chemical phenomena of life that the conviction is widespread that all vital phenomena are capable of a physical explanation. Assuming that conviction to be correct, it is easy to draw the final conclusion that the physical explanation suffices for the entire universe. As to what is, or may be, behind the physical explanation, complete agnosticism is of course the only possible attitude. Such in barest—but I believe correct—outline is the history of modern monism—the doctrine that there is but one kind of power in the universe.

It is evident that monism involves the elimination of two concepts, God and consciousness. It is true that monists sometimes use these words, but it is mere jugglery, for they deny the concept for which the words actually stand. Now, consciousness is too familiar to all men to be summarily cast aside and dismissed. Some way must be found to account for it. From the monistic standpoint there is a choice between two possible alternatives; either consciousness is a form of energy, like heat, etc., or it is merely a so-called epiphenomenon. As there is no evidence that consciousness is a

form of energy, only the second alternative is in reality available, and in fact has been adopted by the monists.

It is essential to have a clear notion of what is meant by an epiphenomenon. Etymologically the word indicates something which is superimposed upon the actual phenomenon. It designates an accompanying incident of a process which is assumed to have no causal relation to the further development of the process. In practice it is used chiefly in regard to the relation of the mind or consciousness to the body, and is commonly employed by those philosophers who believe that consciousness has no causal relation to any subsequent physiological process.

For many years I have tried to recognize some actual idea underneath the epiphenomenon hypothesis of consciousness, but it more and more seems clear to me that there is no idea at all, and that the hypothesis is an empty phrase, a subterfuge, which really amounts only to this—we can explain consciousness very easily by merely assuming that it does not require to be explained at all. Is not that really the confession made by the famous assertion that the consciousness of the brain no more requires explanation than the aquosity of water?

Monism is not a strong system of philosophy, for it is not so much the product of deep and original thinking as the result of a contemporary tendency. It is not the inevitable end of a logical process, because it omits consciousness, but rather an incidental result of an intellectual impulse. Its very popularity betokens its lack of profundity, and its delight in simple formulæ is characteristic of that mediocrity of thought which has much more ambition than real power and accepts simplicity of formularization as equivalent to evidence. It would seem stronger, too, if it were less defended as a faith. Strong partisans make feeble philosophers.

Consciousness ought to be regarded as a biological phenomenon, which the biologist has to investigate in order to increase the number of verifiable data concerning it. In that way, rather than by speculative thought, is the problem of consciousness to be solved, and it is precisely because biolo-

gists are beginning to study consciousness that it is becoming, as I said in opening, the newest problem of science.

The biologist must necessarily become more and more the supreme arbiter of all science and philosophy, for human knowledge is itself a biological function which will become comprehensible just in the measure that biology progresses and brings knowledge of man, both by himself and through comparison with all other living things. We must look to biologists for the mighty generalizations to come rather than to the philosophers, because great new thoughts are generated more by the accumulation of observations than by deep meditation. To know, observe. Observe more and more, and in the end you will know. A generalization is a mountain of observations; from the summit the outlook is broad. The great observer climbs to the outlook, while the mere thinker struggles to imagine it. The best that can be achieved by sheer thinking on the data of ordinary human experience we have already as our glorious inheritance. The principal contribution of science to human progress is the recognition of the value of accumulating data which are found outside of ordinary human experience.

Twenty-three years ago, at Saratoga, I presented before the meeting of this Association—which I then attended for the first time—a paper, "On the Conditions to be Filled by a Theory of Life," in which I maintained that, before we can form a theory of life, we must settle what are the phenomena to be explained by it. So now in regard to consciousness it may be maintained that, for the present, it is more important to seek additional positive knowledge than to hunt for ultimate interpretations. We welcome therefore especially the younger science of experimental psychology, which, it is gratifying to note, has made a more auspicious start in America than in any other country. It completes the circle of the biological sciences. It is the department of biology to which properly belongs the problem of consciousness. The results of experimental psychology are still for the most part future. But I shall endeavor to show that we may obtain some valuable preliminary notions concerning consciousness from our present biological knowledge.

We must begin by accepting the direct evidence of our own consciousness as furnishing the basis. We must further accept the evidence that consciousness exists in other men essentially identical with the consciousness in each of us. The anatomical, physiological and psychological evidence of the identity of the phenomena in different human individuals is, to a scientific mind, absolutely conclusive, even though we continue to admit cheerfully that the epistemologist rightly asserts that no knowledge is absolute, and that the metaphysician rightly claims that *ego* is the only reality and everything else exists only as *ego's* idea, because in science as in practical life we assume that our knowledge is real and is objective in source.

For the purpose of the following discussion we must define certain qualities or characteristics of consciousness. The most striking distinction of the processes in living bodies, as compared with those in inanimate bodies, is that the living processes have an object—they are teleological. The distinction is so conspicuous that the biologists can very often say *why* a given structure exists, or *why* a given function is performed, but *how* the structure exists or *how* the function is performed he can tell very imperfectly, more often not at all. Consciousness is only a particular example; though an excellent one of this peculiarity of biological knowledge—we do not know what it is, we do not know how it functions, but we do know why it exists. Those who are baffled by the elusiveness of consciousness when we attempt to analyze it will do well to remember that all other vital phenomena are in the last instance equally and similarly elusive.

In order to determine the teleological value of consciousness, we must endeavor to make clear to ourselves what the essential function is which it performs. As I have found no description or statement of that function which satisfied me, I have ventured, perhaps rashly, to draw up the following new description:

The function of consciousness is to dislocate in time the reactions from sensations.

In one sense this may be called a definition of conscious-

ness, but inasmuch as it does not tell what consciousness is, but only what it does, we have not a true definition, but a description of a function. The description itself calls for a brief explanation. We receive constantly numerous sensations, and in response to these we do many things. These doings are, comprehensively speaking, our reactions to our sensations. When the response to a stimulus is obviously direct and immediate we call the response a reflex action, but a very large share of our actions are not reflex but are determined in a far more complicated manner by the intervention of consciousness, which may do one of two things: (1) Stop a reaction, as, for example, when something occurs, calling, as it were, for our attention and we do not give our attention to it. This we call conscious inhibition. It plays a great rôle in our lives; but it does not mean necessarily that inhibited impressions may not survive in memory and at a later time determine the action taken; in such cases the potential reaction is stored up. (2) Consciousness may evoke a reaction from a remembered sensation and combine it with sensations received at other times. In other words, consciousness has a selective power, manifest both in choosing from sensations received at the same time and in combining sensations received at different times. It can make synchronous impressions dyschronous in their effects, and dyschronous impressions synchronous. But this somewhat formidable sentence merely paraphrases our original description: The function of consciousness is to dislocate in time the reactions from sensations.

This disarrangement and constant rearrangement of the sensations, or impressions from sensations, which we gather, so that their connections in time are altered seems to me the most fundamental and essential characteristic of consciousness which we know. It is not improbable that hereafter it will become possible to give a better characterization of consciousness. In that case the opinion just given may become unsatisfactory, and have to yield to one based on greater knowledge. The characteristic we are considering is certainly important, and so far as the available evidence goes it belongs

exclusively to consciousness. Without it life would have no interest, for there would be no possibility of experience, no possibility of education.

Now the more we have learned about animals, the better have we appreciated the fact that in them only such structures and functions are preserved as are useful, or have a teleological value. Formerly a good many organs were called rudimentary or vestigial and supposed to be useless survivals because they had no known function. But in many cases the functions have since been discovered. Such, for example, were the pineal gland, the pituitary body, the suprarenal capsules and the Wolffian body of man, all of which are now recognized to be functionally important structures. Useless structures are so rare that one questions whether any exist at all, except on an almost insignificant scale. It has accordingly become well-nigh impossible for us to imagine consciousness to have been evolved, as it has been, unless it had been bionomically useful. Let us therefore next consider the value of consciousness from the standpoint of bionomics.*

We must begin with a consideration of the nature of sensations and the object of the reactions which they cause. In the simpler forms of nervous action a force, usually but not necessarily external to the organism, acts as a stimulus which causes an irritation; the irritation produces a reaction. Within the ordinary range of the stimuli to which an organism is subjected, the reaction is teleological, that is, it tends to the benefit of the organism. A familiar illustration is the presence of food in the stomach, which produces a stimulus, the reaction to which is manifested by the secretion of the digestive fluid for the purpose of digesting the food. An organism might conceivably be maintained solely by this mechanism in cooperation with the physical laws which govern all matter. Life in such an organism would be a succession

*A convenient term, recently gaining favor, for what might otherwise be called the economics of the living organism. Bionomics seems preferable to *ecology*, which some writers are adopting from the German.

of teleological processes, essentially mechanical and regulated automatically by the organism. By far the majority of biologists regard plants as essentially conforming to this type of life. Whether they absolutely so conform we do not, of course, yet know.

A sensation involves the interpolation of consciousness between the stimulation and the reaction, and in consequence there is established the possibility of a higher order of adjustment to the external world than can be attained through the teleological reaction to a stimulus. This possibility depends upon the fact that the intervention of consciousness permits an adjustment in accordance not merely with the immediate sensation, but also, and at the same time, in accordance with earlier sensations. Thus, for example, the child sees an object, and its reaction is to take hold of the object, which is hot and hurts the child. Later the child sees the object again and its natural reaction is to take hold of it again, but the child now reacts differently because its consciousness utilizes the earlier as well as the present sensation; the previous sensation is dislocated in time and fused with the present sensation and a new reaction follows. No argument is necessary to establish the obvious conclusion that an organism which has consciousness has an immensely increased scope for its adjustments to the external conditions; in other words consciousness has a very high value for the organism. It is unnecessary to dwell upon this conclusion, for it will be admitted by every one, except perhaps those who start with the *a priori* conviction that consciousness is an epiphenomenon.

A sensation gives information concerning the external world. Perhaps science has achieved nothing else which has done so much to clarify philosophy as the demonstration that the objective phenomena are wholly unlike the subjective sensations. Light is a series of undulations, but we do not perceive the undulation as such, but as red, yellow and green, or as we say colors; the colors give us available information, we use them as so many labels, and we learn that reactions to these labels may be helpful or hurtful, and so we regulate our conduct. Objectively red, yellow and green do not exist.

Similarly with the vibrations of the air, certain of which cause the sensation of sound, which is purely subjective. But the sound gives us information concerning our surroundings, which we utilize for our teleological needs, although in nature external to us there is no sound at all. Similarly all our other senses report to us circumstances and conditions, but always the report is unlike the external reality. Our sensations are symbols merely, not images. They are, however, bionomically sufficient because they are constant. They are useful not because they copy the external reality or represent it, but because, being constant results of external causes, they enable consciousness to prophesy or foresee the results of the reactions of the organism, and to maintain and improve the continual adjustment to the external reality.

The metaphysicians have for centuries debated whether there is any external objective reality. Is it too much to say that the biological study of consciousness settles the debate in favor of the view that the objective world is real?

Consciousness is not only screened from the objective world from which it receives all its sensations, but also equally from immediate knowledge of the body through which it acts. As I write this sentence I utilize vaso-motor nerves, regulating the cerebral blood currents, and other nerves which make my hand muscles contract and relax, but of all this physiological work my consciousness knows nothing though it commands the work to be done. The contents of consciousness are as unlike what is borne out from it as they are unlike what is borne into it.

The peculiar untruthfulness to the objective which consciousness exhibits in what it gets and gives would be perplexing were it not that we have learned to recognize in consciousness a device to secure better adjustment to external reality. For this service the system of symbols is successful, and we have no ground for supposing that the service would be better if consciousness possessed direct images or copies instead of symbols of the objective world.

Our sensory and motor* organs are the servants of con-

*And other organs in efferent relations to consciousness.

sciousness; its messengers or scouts; its agents or laborers; and the nervous system is its administrative office. A large part of our anatomical characteristics exist for the purpose of increasing the resources of consciousness, so that it may do its bionomic function with greater efficiency. Our eyes ears, taste, etc., are valuable, because they supply consciousness with data; our nerves, muscles, bones, etc., are valuable, because they enable consciousness to effect the needed reactions.

Let us now turn our attention to the problem of consciousness in animals. The comparative method has an importance in biology which it has in no other science, for life exists in many forms which we commonly call species. Species, as I once heard it stated, differ from one another with resemblance. The difference which resembles we term an homology. Our arm, the bird's wing, the lizard's front leg are homologous. The conception of homology both of structure and of function lies at the basis of all biological science, which must be and remain incomprehensible to any mind not thoroughly imbued with this conception. Only those who are deficient in this respect can fail to understand that the evidence is overwhelming that animals have a consciousness homologous with the human consciousness. The proof is conclusive. As regards at least mammals—I think we could safely say as regards vertebrates—the proof is the whole sum of our knowledge of the structure, functions and life of these animals.

As we descend the animal scale to lower forms there is no break and therefore no point in the descent where we can say here animal consciousness ends, and animals below are without it. It seems inevitable therefore to admit that consciousness extends far down through the animal kingdom, certainly at least as far down as there are animals with sense organs or even the most rudimentary nervous system. It is unsatisfactory to rely chiefly on the anatomical evidence for the answer to our query. We await eagerly results from psychological experiments on the lower invertebrates. A sense organ however implies consciousness, and since such organs occur among cœlenterates we are led to assign consciousness to these animals.

The series of considerations which we have had before us lead directly to the conclusion that the development and improvement of consciousness has been the most important, really the dominant, factor in the evolution of the animal series. The sense organs have been multiplied and perfected in order to supply consciousness with a richer, more varied and more trustworthy store of symbols corresponding to external conditions. The nervous system has grown vastly in complexity in order to permit a constantly increasing variety in the time dislocations of sensation. The motor and allied apparatus have been multiplied and perfected in order to supply consciousness with more possibilities of adjustment to external reality which might be advantageous.

If we thus assign to consciousness the leading rôle in animal evolution we must supplement our hypothesis by another, namely, that conscious actions are primary; reflex and instinctive actions secondary, or, in other words, that, for the benefit of the organism, conscious actions have been transformed into reflexes and instincts. Unfortunately we must rely chiefly on future physiological and psychological experiments to determine the truth of this hypothesis. Its verification, however, is suggested by certain facts in the comparative physiology of the vertebrate nervous system, which tend to show that in the lower forms (amphibia) a certain degree of consciousness presides over the functions of the spinal cord, which in mammals is devoted to reflex actions. Its verification is further suggested by the natural history of habits. As we all know, new actions are performed with difficulty and slowly, but if often repeated they are soon easier and more rapid. If a given reaction to a sensation of group of sensations through consciousness is advantageous to the organism and the environment is such that the sensation is often repeated, then a habit is formed and the response becomes more rapid, and often in ourselves we see habits which arose from conscious action working almost without the participation of consciousness, and moreover working usefully because rapidly. The usefulness of conscious reactions is that they are determined not merely by the present sensation, but

also by past sensations, but they have the defect that they are slow. We can readily understand that it would aid an organism to have the quicker reaction substituted, and we thus recognize a valid teleological reason for the replacement of conscious action by habits in the individual, by instincts in the race. The investigation of the evolution of reflexes and instincts is one of the important and most promising tasks of comparative psychology.

A frank unbiased study of consciousness must convince every biologist that it is one of the fundamental phenomena of at least animal life, if not, as is quite possible, of all life. Nevertheless its consideration has barely a place in biological science, although it has long occupied a vast place in philosophy and metaphysics. If this address shall contribute to a clearer appreciation of the necessity of treating consciousness as primarily a problem for biological research to solve, my purpose will be achieved. In an ideal world philosophers and scientists would be identical; in the actual world there are philosophical scientists and scientific philosophers, but in the main the followers of the two disciplines pursue paths which are unfortunately distinct. The philosophical mind is of a type unlike the scientific. The former tries to progress primarily by thought based on the data available, the latter seeks to advance primarily by collecting additional data. The consequence of this difference is that philosophy is dependent upon the progress of science, but we who pursue the scientific way make no greater mistake than to underestimate philosophy. The warning is needed. Data of observation are a treasure and very precious. They are the foundation of our mental wealth, but that wealth consists of the thought into which the data are transmitted. In pleading therefore for an increased observational study of consciousness, we plead not merely for science, but equally for philosophy. The scientific progress must come first. Hence we urge the advantage of investigating consciousness in its immediate revelations which are accessible now. Let us give up the ineffectual struggle to discover the essential nature of consciousness until we can renew it with much larger resources of knowledge.

The psychologists ought now to apply the comparative method on a grand scale. They are just beginning to use it. Years of patient labor must pass by, but the reward will be very great. The psychic life of animals must be minutely observed, the conditions of observation carefully regulated, and the results recorded item by item. The time has passed by for making generalizations on the basis of our common, vague and often inexact notions concerning the habits of animals. Exact experimental evidence will furnish a rich crop of psychological discovery. Scientific psychology is the most backward in its development of all the great divisions of biology. It needs, however, little courage to prophesy that it will bring forth results of momentous importance to mankind. After data have been gathered, generalization will follow which, it may be hoped, will lead us on to the understanding of even consciousness itself.

The teleological impress is stamped on all life. Vital functions have a purpose. The purpose is always the maintenance of the individual or of the race in its environment. The entire evolution of plants and animals is essentially the evolution of the means of adjustment of the organism to external conditions. According to the views I have laid before you, consciousness is a conspicuous, a commanding, factor of adjustment in animals. Its superiority is so great that it has been, so to speak, eagerly seized upon by natural selection and provided with constantly improved instruments to work with. A concrete illustration will render the conception clearer. In the lowest animals, the cœlenterates, in which we can recognize sense organs, the structure of them is very simple, and they serve as organs of touch and of chemical sensation resembling taste. In certain jelly fishes we find added special organs of orientation and pigmented spots for the perception of light. In worms we have true eyes and vision. In vertebrates we encounter true sense of smell. Fishes cannot hear, but in the higher vertebrates, that is from the amphibians up, there are true auditory organs. In short, both the senses once evolved are improved and also new senses are added. It is perfectly conceivable that there should be yet

other senses, radically different from any we know. Another illustration, and equally forcible, of the evolution of aids to consciousness might be drawn from the comparative history of the motor systems, passing from the simple contractile thread to the striated muscle fiber, from the primitive diffuse musculature of a hydroid to the highly specialized and correlated muscles of a mammal.

It is interesting to consider the evolution of adjustment to external reality in its broadest features. In the lowest animals the range of the possible adjustment is very limited. In them not only is the variety of possible actions small, but they cover also a small period of time. In animals which have acquired a higher organization the adjustments are more complex, both because the reactions are more varied and because they cover a longer period of time. Thus the jelly fish depends upon such food as happens to come within its reach, seizing from moment to moment that which it encounters; but a lobster pursues its food, making complicated movements in order to reach it and seize it. One can trap lobsters easily; I doubt if one could trap a jelly fish at all. The next great advance is marked by the establishment of communication between individuals of the same species. About this phenomenon we know exceedingly little; the investigation of it is one of the most important duties of the comparative physiologist. Its bionomic value is obviously great for it allows an individual to utilize the experience of another as well as its own. We might, indeed, compare it with the addition of a new sense, so greatly does it extend the sources of information. The communication between individuals is especially characteristic of vertebrates, and in the higher members of that subkingdom it plays a very great rôle in aiding the work of consciousness. In man, owing to articulate speech, the factor of communication has acquired a maximum importance. The value of language, our principle medium of communication, lies in its aiding the adjustment of the individual and the race to external reality. Human evolution is the continuation of animal evolution, and in both the dominant factor has been the increase of the resources available for consciousness.

In practical life it is convenient to distinguish the works of nature from the works of man, the "natural" from the "artificial." The biologist, on the contrary, must never allow himself to forget that man is a part of nature and that all his works are natural works. This is specially important for the present discussion, for otherwise we are likely to forget also that man is as completely subject to the necessity of adjustment to external reality as any other organism. From the biological standpoint all the work of agriculture, of manufactures, of commerce and of government is a part of the work of consciousness to secure the needed adjustments. All science belongs in the same category as the teleological efforts of a jelly fish or a lobster. It is work done at the command of consciousness to satisfy the needs of existence. The lesson of all this to us is that we should accustom ourselves to profit by our understanding of the trend of evolution, which, in the progress humanity makes, obeys the same law of adaptation to objective reality which has controlled the history of animals. This view of the conditions of our existence puts science in its right place. As all sensations are symbols of external reality useful to guide organisms to teleological reactions, so is all science symbolic and similarly useful.

Nature never produces what to us seems a perfect organism, but only organisms which are provided with means of adjustment sufficient to accomplish the survival and perpetuation of the species. Man also is imperfect, but in the struggle for existence wins his way because his consciousness has greater resources than that of any other organism. His great power arises from his appreciation of evolution. His highest duty is to advance evolution, and this duty must be most strongly felt by those who accept the religious interpretation of life. The advancement of science is an obligation. To this view of the work of our Association I may safely claim the assent of all present.

The function of science is to extend our acquaintance with the objective world. The purpose of the American Association is not alone to increase the sum total of science, but equally also to preach by word and precept the value of

truth, truth being the correct conscious symbol of the objective, by utilizing which our purposeful reactions are improved. The most serious obstacle truth encounters is the prevalence of what I may call "doll ideas"—by analogy with the material dolls, with which children play. The child makes believe with the doll, knowing all the time its unreality, assigns to it hopes, passions, appetites; the child may feel the intensest sympathy with its doll, weep at its sorrows, laugh over its joys, yet know always that it is a mere inanimate, senseless doll. Adult men and women have ideas, with which they play make-believe; doll ideas, which they know are unreal, and yet they mourn sincerely over the adversities of their mental dolls, rejoice over their successes, and fight for them with passion. Such doll ideas become mingled with the real and inextricably woven into the fabric of life. They are treated with the most earnest seriousness. Men will fight for them as a child will fight for its doll, not because it is property, but because it is a sacred personality. So are doll ideas often made sacred and defended with fanaticism. Yet, behind, in consciousness is the sense of unreality, the disregarded admission of "making believe." Do not doll ideas, pseudo-opinions, play a great rôle in human life? I think they do, and thinking so, deem it all the more imperative that you and others should teach the people the standard of science, the humble acknowledgment of reality. I wish that an impulse toward this goal from our Association could be imparted to every man and woman in the country, and I hope that the Association may continue to grow in number and power for long years to come, as it has grown in the last few years, so that it shall be a national, all-pervading influence serving the truth.

It seems to me inconceivable that the evolution of animals should have taken place as it actually has taken place, unless consciousness is a real factor and dominant. Accordingly I hold that it actually affects the vital processes. There is, in my opinion, no possibility of avoiding the conclusion that consciousness stands in immediate causal relations with physiological processes. To say this is to abide by the facts, as at present known to us, and with the facts our conceptions must be made to accord.

The thought which I wish to emphasize is the importance for the future investigation of consciousness of separating the study of what it does from the study of what it is. The latter study is recondite, metaphysical, and carries us far beyond the limits of verifiable human knowledge. The former study is open to us and offers opportunities to science, but it has hitherto been almost completely neglected. Biology has now to redeem itself by effectual researches on consciousness. On the adequate prosecution of such researches we base great hopes.

Before I close permit me a few words concerning the relations of consciousness to the body, to living substances through which it manifests itself. It is intimately linked to protoplasm. Probably no question is so profoundly interesting to all mankind as the old question, what is the relation of the mind to the body? It is a question which has been stated in many forms and from many points of view, but the essential object of the question is always the same, to ask whether consciousness is a function of living matter, or something discreet and not physical or material.

Throughout this address consciousness has been viewed as a device to regulate the actions of the organisms so as to accomplish purposes which on the whole are useful to the organisms, and accordingly we have termed its function teleological. If this view is correct it accounts for the limitations of consciousness, its mechanical mode of work, its precision and definiteness of action, for, of course, unless consciousness is orderly and obeys laws, it cannot be of use to the organism, but, on the contrary, it would be harmful, and conscious animals would have ceased long ago to survive. The very fact that consciousness is of such high value in the bionomy of an animal renders it obvious that it must be subject to law. Accordingly it appears to us regulated as do the functions of protoplasm. Hence to certain modern thinkers it presents itself as a function of protoplasm, or, as it may be better stated, as a state or condition of protoplasm.

The internal evidence of consciousness, however, is against this view and presents to us conscious actions as depending

upon the consciousness. As before stated I believe that this evidence must be accepted. Now all the sensations of consciousness are derived from physical force, and all the acts of consicousness are manifested through physical force; hence if it has any real power consciousness must be able to change the form of energy. Unless we accept this doctrine, we must give up all belief in free-will and adopt the automaton theory of life. Is not the more reasonable explanation that which is based upon all the contents of our consciousness rather than that which we can draw by discarding the internal evidence which consciousness brings us? The hypothesis which I offer for your consideration is this:

Consciousness has the power to change the form of energy, and is neither a form of energy nor a state of protoplasm.

By this hypothesis there are two fundamentally different things in the universe—force and consciousness. You ask why I do not say three, and add matter? My answer is that we do not have, and never have had, any evidence whatever that matter exists. All our sensations are caused by force and by force only, so that the biologist can say that our senses bring no evidence of matter. The concept "matter" is an irrational transfer of notions derived from the gross molar world of the senses to the molecular world. Faraday long ago pointed out that nothing was gained and much lost by the hypothesis of material atoms, and his position seems to me impregnable. It would be a great contribution to science to kill off the hypothesis of matter as distinct from force.

To conclude: The universe consists of force and consciousness. As consciousness by our hypothesis can initiate the change of the form of energy, it may be that without consciousness the universe would come to absolute rest. Since I close with a bold speculation let my last words recall to you that my text is: Investigate consciousness by comparative observations. Only from observation can we know. Correct, intelligent, exhaustive observation is our goal. When we reach it human sicence will be completed.

SECTION A.

Mathematics and Astronomy.

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C. L. DOOLITTLE.

ADDRESS

BY

JAMES McMAHON,

VICE-PRESIDENT AND CHAIRMAN OF SECTION A, FOR 1901.

SOME RECENT APPLICATIONS OF FUNCTION-THEORY TO PHYSICAL PROBLEMS.

It has seemed appropriate that the address of the retiring chairman should draw attention to some of the most recent developments in those sciences which it is the object of this Section of the Association to promote, especially to some problems that seem to be making but slow headway, and to others that are at a standstill for want of appropriate modes of mathematical expression.

In selecting a particular group of problems, I have been guided by the thought that there is one field of work which touches the domain of every member of this Section, whether his or her immediate interests lie in abstract mathematics, in physical mathematics, or in astronomy. I mean the great field of the theory of functions of a complex variable.

The physicist or astronomer who wishes to understand the true nature of any function which he deals with must study its behavior on the complex plane, its zeros, its poles, its singularities, and perhaps its Riemann surface. Moreover, in dealing with such important questions as stability and instability, it is necessary to examine the region of convergence of the infinite series which so often present themselves; and this cannot be done with certainty without the methods of function-theory.

In such cases we use the function-theory to test the character of the solutions already obtained; and to find out the

regions within which they are applicable; but in the discovery of solutions of new physical problems the methods of general function-theory have seldom been used. It is chiefly of its use as an instrument of discovery that I wish to speak to-day.

It has long been known that the theory of functions of a complex variable is useful in treating of the numerous physical problems whose solution can be made to depend on Laplace's equation in two dimensions

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0 .$$

This equation presents itself in the theory of the two-dimensional potential, and in problems relating to the steady flow of heat, of electricity, and of incompressible fluids.

The essential feature of the method in question is to take an arbitrary function of the complex variable, and to express this function in the form

$$f(x + iy) = \varphi(x, y) + i\psi(x, y) ,$$

in which φ and ψ are real functions of two real variables x and y.

The functions φ and ψ are then said to be conjugate to each other, and are in all cases solutions of Laplace's equation, whatever be the assumed function f.

Moreover, the two families of curves

$$\varphi(x, y) = c_1 , \quad \psi(x, y) = c_2 ,$$

(in which c and c_2 are arbitrary constant parameters) cut each other at right angles. The curves of one system may be taken as equipotential lines and those of the other system will then be lines of force, or lines of flow. The physical boundary of the region must be some one of the lines of either set.

Some interesting applications of this method to tidal theory have recently been made by Dr. Rollin A. Harris in his Manual of the Tides, published by the Coast Survey.* I

*Manual of Tides, Part IV A, (Washington, 1901), pp. 574-82.

would mention especially his use of an elliptic function as the transforming function, in the form

$$x + iy = \operatorname{sn}(\varphi + i\psi).$$

The two sets of orthogonal curves drawn by him may be seen in the Annals of Mathematics, Vol. IV, page 83. By imagining thin walls erected along certain of the stream lines, we see, for instance, the nature of the flow around an island lying between two capes.

The direct problem of determining a solution of Laplace's equation that shall be constant at all points of a boundary previously assigned is usually very difficult. It is a particular case of what is commonly known as the problem of Dirichlet. Before stating this problem it is convenient to define a harmonic function. Any real function $u(x, y, z)$ which satisfies Laplace's equation, and which, together with its derivatives of the first two orders, is one-valued and continuous within a certain region, is said to be *harmonic* within that region. Dirichlet's problem may then be stated as follows:

To find a function $u\ (x, y, z)$ which shall be harmonic within an assigned region T, and which shall take assigned values at points on the bounding surface S.

This problem has long been one of the meeting grounds of mathematicians and physicists. Some important mathematical theories have received their starting point from this and similar boundary-value problems.

In proving that a solution always exists, Dirichlet began by assuming as self-evident that among all the functions which satisfy the assigned boundary conditions, there is a certain function u for which the integral

$$\iiint\left[\left[\frac{\partial u}{\partial x}\right]^2 + \left[\frac{\partial u}{\partial y}\right]^2 + \left[\frac{\partial u}{\partial z}\right]^2\right] dx\, dy\, dz,$$

taken throughout the region T, is a minimum. This assumption is usually called Dirichlet's principle. If this principle be granted it can be shown by the Calculus of Variations that the function u satisfies Laplace s equation; and it is easy to

prove by an application of Green's theorem that there is no other solution.

It was first pointed out by Weierstrass that this assumption is not allowable. If only a finite number of quantities present themselves we can assume that there is a smallest one among them; but among an indefinite number of quantities in any assigned group a smallest one does not necessarily exist. Consider, for instance, those rational numbers which decrease towards the square root of 2 as a limit; there is no smallest among them.

This led mathematicians to seek for other proofs of the existence-theorem; and many interesting developments in function-theory have been the result. Very recently Hilbert has re-examined Dirichlet's assumption, and has succeeded in demonstrating it, so that it is once more available as a starting-point for the existence-theorem.

When the boundary of the region is rectangular, circular, spherical, cylindrical, conical, or ellipsoidal, the appropriate harmonic functions will be found in such works as Byerly's "Fourier Series and Spherical Harmonics."

I may mention here a new method of obtaining solutions of Laplace's three-dimensional equation used by Dr. Harris and applied to tidal problems.* He uses the more general complex variable containing two imaginary units i and j. An arbitrary function of the form

$$\varphi\,(ax + iby + jcz)$$

is a solution of Laplace's equation, provided $i^2 = j^2 = -1$ and $a^2 = b^2 + c^2$; and when this function is expanded, the real part, and the coefficients of i, of j and of ij, are all separate solutions of the differential equation. A great number of solutions of this and similar equations can be obtained by this method. It is to be hoped that Dr. Harris may have time to develop it further.

In order to lead up to some recent applications of function-theory, I wish to speak especially of another method of solv-

*Manual of Tides, Part IV A, pp. 584 and 597.

ing Dirichlet's problem, namely, by the use of Green s function.

Green's function is defined as follows for a given closed boundary S and a given pole P_1 within the bounded region T. Let (x, y, z) be the current point within the region, and let (x_1, y_1, z_1) be the pole. Then $G^{x,\ y,\ z,}_{x_1, y_1, z_1,}$ is to vanish at every point of the boundary S, and is to be harmonic within the region T except at the pole (x_1, y_1, z_1), where it is to become infinite as $\frac{1}{r}$, in which r is the distance of the current point (x, y, z) from (x_1, y_1, z_1).

There is always one and only one Green's function for a given boundary and pole. The determination of the form of such function furnishes a solution of Dirichlet's problem; for it has the property that the surface integral

$$\iint V \frac{dG}{dn} dS,$$

taken over the boundary of S, has the value $4\pi V\ (x_1, y_1, z_1)$, where V is any function harmonic within T, and $\frac{dG}{dn}$ is the normal derivative of Green's function. Hence the value of V at any point (x_1, y_1, z_1) within the boundary is expressible in terms of its surface values and the normal derivative $\frac{dG}{dn}$. Thus the solution of Dirichlet's problem is reduced to a problem in integration when Green's function is known.

Some important recent advances have been made in determining Green's function for certain boundaries. To make them clearer I shall begin with the simple problem of finding Green's function for a region bounded by two planes at right angles and extending to infinity. Here Lord Kelvin's method of images is directly applicable. Let P_2 be the image of the pole P_1 taken with regard to the first plane. Let P_3 be the image of P_2 with regard to the second plane; and P_4 the image of P_3 as to the first plane. Then the image of P_4 as to the second plane brings us back to the first point P_1. These four

poles form a closed system, and there is only one pole in the given region. The required Green's function is

$$\frac{1}{r_1} - \frac{1}{r} + \frac{1}{r_3} - \frac{1}{r_4}$$

in terms of the distances of the current point (x, y, z) from the four poles. For this function, being a potential function, satisfies Laplace's equation; it also vanishes on the bounding planes by symmetry, and at infinity; moreover, it becomes infinite as $\frac{1}{r}$ at the pole P_1, and is infinite nowhere else within the bounded region.

It may be observed that a direct physical interpretation of Green's function is illustrated by this problem. It is evidently the combined potential due to a positive unit of electricity placed at P_1 and to the induced charge on the bounding planes, made conducting and maintained at zero potential; for this distribution realizes the boundary conditions. Hence the induced charge due to P_1 is equivalent in effect to three point-charges, namely, a positive unit at P_3 and negative units at P_2 and P_4.

Next consider the problem in which the angle of the planes is not an aliquot part of π. The simplest case is when this angle is $\frac{2}{3}\pi$. Performing the successive reflections as before, it is found that there are five reflections before the image comes back to P_1. There are then six poles, of which two are situated in the given region. The function

$$\frac{1}{r_1} - \frac{1}{r_2} + \frac{1}{r_3} - \frac{1}{r_4} + \frac{1}{r_5} - \frac{1}{r_6}$$

satisfies all the conditions except that of having only one pole within the region. It is thus not the required Green's function; and Lord Kelvin's method of images does not furnish a solution.

This method fails in two large classes of problems: (1) when the successive images (or poles) do not form a closed system; (2) when more than one of these poles lie within the assigned region.

By the conception of a Riemann space, Professor Sommerfeld* has recently made the important advance of overcoming the difficulty arising from the presence of two poles within the region. He regards the whole region as undergoing successive reflection; and thus, in the problem last mentioned, the whole of space is filled twice over. He imagines a twofold Riemann space having the intersection of the planes as a winding line, and one of the planes as a branch membrane. The appropriate coordinates are cylindrical (r, θ, z). The axis of z is the line of intersection, and the plane $z = 0$ is the plane passed through the original pole P_1 perpendicular to the axis of z. The radius-vector r is the distance of the current point from the z-axis, and θ is the angle which r makes with one of the planes, taken as initial plane.

When any radius-vector oP revolves about the axis of z, it remains in the first (or physical) space until $\theta = 2\pi$. It then crosses the branch membrane and enters the second fold of the Riemann space. In the problem before us, a second revolution brings the radius-vector into the first fold again. It is to be understood that each fold fills all space. Two underlying points have the same r and the same z, but their θ-coordinates differ by 2π or some odd multiple of 2π. Two points whose vectorial angles differ by an even multiple of 2π are in the same fold.

The problem now is to find a harmonic function which shall vanish on each plane and shall have only one pole in the original physical space between the planes.

Let $(r_1, \theta_1, 0)$ be the coordinates of the assigned pole, and (r, θ, z) those of the current point. Then $\frac{1}{R}$ is a solution of Laplace's equation, where

$$R^2 = r^2 + r_1^2 - 2rr_1 \cos(\theta - \theta_1) + z^2 .$$

Dr. Sommerfeld first replaces θ_1 by an arbitrary parameter a, and denotes the result by R^1. He then multiplies $\frac{1}{R^1}$ by an

*Proc. London Math. Soc., 1897, "Ueber verzweigte Potentiale im Raum."

arbitrary function $f(a)$, and integrates with regard to a. The result is still a solution of Laplace's equation. By a proper choice of the function f, and of the range of integration, he obtains a function of (r, θ, z) satisfying all the conditions. He takes

$$f(a) = \frac{e^{\frac{1}{2}ia}}{e^{\frac{1}{2}ia} - e^{\frac{1}{2}i\theta_1}},$$

and puts

$$u_1 = \frac{1}{4\pi} \int \frac{1}{R^1} f(a)\, da,$$

then regards a as a complex number, and performs the integration in the a-plane around a contour enclosing the point $a = \theta_1$, and excluding the other points where the integrand becomes infinite. The function u_1 thus obtained becomes infinite at the pole $(r_1, \theta_1, 0)$, but does not fulfill the condition of vanishing on the two planes. Sommerfeld next forms a similar function u_2 for the second pole $(r_2, \theta_2, 0)$, and so on. The required Green's function is

$$u = u_1 - u_2 + u_3 - u_4 + u_5 - u_6 .$$

The poles of u_1 and u_4 would, under ordinary circumstances, both lie in the given region, but the pole of u_4 is given such a vectorial angle as to bring it into the second fold of the Riemann space. The function u has then only one pole for the physical region defined by $0 < \theta < 2\pi$.

Moreover u vanishes for points on the two planes, and at infinity, and satisfies all the other conditions for Green's function.

Thus we see how a function, which would be two-valued and bi-polar if restricted to the given physical region, becomes single-valued and uni-polar in the Riemann space. We may say that the second fold of this space is a refuge for the second value and the second pole. Care has to be taken to use the proper values for θ when the indicated operations are being performed. These require skill in the deformation of the

path of integration. The difficulties of the problem are thus reduced to those of the Integral Calculus. In the more general case in which the angle of the planes is $\frac{n}{m}\pi$, there are $2n$ poles in the circuit (one in each angle $\frac{\pi}{m}$), of which n are in the given region. The Riemann space is then n-fold.

Sommerfeld has worked out at length the very interesting case in which the angle between the planes is 2π. The region is then bounded by the surfaces $z = \pm \infty$, $r = \infty$, $\theta = 0$, $\theta = 2\pi$; the last two being the two faces of an infinite half plane with a straight edge. The assigned pole and its image are both in the given region; hence, the corresponding Riemann space is two-fold, and the required solution is

$$\bar{u} = u\,(\theta_1) - u\,(-\theta_1)\,,$$

where u is of the same form as u_1 written above.

By inversion with regard to different centers, various other problems are reduced to this one; for instance, the case of the infinite plane with a circular aperture, the circular disc, and the spherical segment.

With regard to the uniqueness of the solution Sommerfeld has proved, by a remarkable use of function-theory methods, that a function satisfying the conditions already laid down for Green's function is uniquely determined in a Riemann space.

I next speak of some recent advances in the solution of an equation more general than Laplace's, namely, the differential equation

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} + k^2 u = 0\,,$$

which plays such an important part in the treatment of vibrating systems of various kinds; and I may introduce them by a quotation from Pockels' treatise on this equation.

"Those solutions of our differential equation, which, in accordance with their physical significance, are regarded as single-valued within certain bounded regions, would by an-

alytical continuation over the boundary in general become multiform. Therefore, both from a mathematical and physical standpoint, multiform functions are important, and it is very desirable that the properties of such functions, their winding points and singularities, their behavior on Riemann surfaces, etc., should be systematically investigated—in short, all the function-theory questions which were handled in the theory of the Newtonian and Logarithmic potential. . . .

"Similarly as we have treated of solutions that are single-valued in the whole plane, it would be of interest to seek functions which are single-valued on a closed Riemann surface, or in an analogous three-dimensional region, more especially those functions which are everywhere finite and continuous, namely, the so-called 'principal solutions' within the region in question. Finally there is the further investigation of the essential singularities, and the natural boundaries which the functions satisfying this equation may present. . . .

"Investigations regarding these questions have not yet been made, more especially the integration of our equations for a closed manifold has hardly been touched. In this direction of inquiry without doubt a wide and rich field offers itself."

These words were written in 1890, and in 1897 appeared Professor Sommerfeld's suggestive paper on multiform potential functions of which I have given some account above. He and his pupil, Dr. Carslaw, have also attacked the multiform solutions* of the more general equation to which Pockels refers.

The first problem that presents itself is to find a solution that has no pole, and is multiform with period $2n\pi$ in the ordinary sense, but on a certain n-sheeted Riemann surface is uniform. The case $n = 2$ solves the following well-known physical problem:

Plane waves of sound, light or electricity are incident on a thin infinite half-plane bounded by a straight edge, to find the resulting diffraction of the waves.

*Proc. Lond. Math. Soc., 1898. "Some multiform solutions of the Partial Differential Equations of Physical Mathematics and their Applications."

This problem had previously been mentioned by Lord Rayleigh in the article on Wave Theory in the Encylopedia Britannica in the following terms: "The full solution of problems concerning the mode of action of a screen is scarcely to be expected. Even in the simple case of sound where we know what we have to deal with, the mathematical difficulties are formidable, and we are not able to solve such an apparently elementary question as the transmission of sound past a rigid infinite thin plane screen bounded by a straight edge or perforated with a circular aperture."

Again the same author says in his work on the Theory of Sound:* "The diffraction of sound is a subject which has attracted but little attention either from mathematicians or experimentalists. Although the general character of the phenomena is well understood, and therefore no very striking discoveries are to be expected, the exact theoretical solution of a few of the simpler problems, which the subject presents, would be interesting."

Accordingly the recent solutions of Sommerfeld and Carslaw are very welcome to mathematicians and physicists. A very brief sketch of the principle of the method may here be given.

Let the waves come from the direction $\theta = \theta_1$, and be incident on the plane $\theta = 0$, the direction of the waves being perpendicular to the straight edge. In the (x, y) plane, or in the (r, θ) plane, the origin will be regarded as a winding point, and the line $\theta = \pi + \theta_1$ a branch line. Start with the simplest two-dimensional solution of our differential equation, namely, that for undisturbed plane waves in infinite space,

$$u = e^{ir\cos(\theta - \theta_1)},$$

replace θ_1 by α, multiply by the same twofold function of α as before, and integrate around the point $\alpha = \theta_1$ in the complex α-plane. The result of the integration is a multiform solution of period 4π. The solution of the physical problem is obtained by adding the multiform solution for waves coming from the direction θ_1 to that for the direction $-\theta_1$. There is, of course,

*Theory of Sound, Vol. II, p. 141.

considerable difficulty in performing the indicated operations, but this does not diminish the theoretical value of the solution, as the difficulties belong only to the Integral Calculus.

The three-dimensional problem in which the edge of the plane is not perpendicular to the direction of the waves has also been treated by Dr. Carslaw.*

The next problem in order is that of waves issuing from a point-source against the infinite half-plane, either in two or in three dimensions.

In the latter case we start with the undisturbed solution in infinite space

$$u = \frac{e^{-ikR}}{R},$$

and treat this function as we treated $\frac{1}{R}$ in the potential problem.

We put poles at $(r_1, \theta_1 \, 0,)$ and $(r_1, -\theta_1, 0)$, and take the physical space as defined by $0 < \theta < 2\pi$.

It will be found that the function

$$\bar{u} = u(\theta_1) - u(-\theta_1)$$

satisfies all the assigned conditions in the physical space.

In the corresponding two-dimensional problem, the starting point is the undisturbed solution

$$u = Y_0 (kR),$$

where Y_0 is the Neumann function.

The same method is applicable to problems in the flow of heat, in which the equation

$$k\left[\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right] = \frac{\partial u}{\partial t}$$

is to be satisfied. The starting point is the solution for a point-source in an infinite solid

$$u = \frac{1}{(4\pi kt)^{\frac{3}{2}}} \, exp\left[\frac{-R^2}{4kt}\right].$$

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*Proc. Edinburgh Math. Soc., 1901.

In a recent paper published in the Zeitschrift,* Sommerfeld has extended the method so as to apply to the problem of Röntgen Rays encountering an obstacle represented by the same half-plane. He obtains a multiform solution of Maxwell's equations, and adapts it to the physical conditions, comparing the results with experimental data.

The induced currents flowing in an infinite half-plane have been studied by Mr. Jeans† by the multiform method, using a Riemann space with a single winding line.

The next advance was to solve a problem in multiform potentials in a Riemann space with two winding lines. Such a case presents itself in finding Green's function for an infinite plane with an infinitely long strip cut out. Sommerfeld has treated this problem by the use of the bi-polar coordinate system

$$\rho = \log \frac{r_1}{r_2},\ \varphi = \theta_1 - \theta_2.$$

This is the system used so skilfully by Maxwell, in which the loci $\rho = C_1$, $\varphi = C_2$, form two series of orthogonal circles (or cylinders). The Riemann surface has two winding lines corresponding to $\rho = \pm \infty$, and a branch membrane $\varphi = 0$.

The work of obtaining solutions of our differential equations on other Riemann surfaces has yet to be done. The difficulty lies in finding an appropriate system of coordinates. This is an attractive field, and it seems worthy of the attention of the best pure mathematicians.

It is interesting to note that the idea of obtaining a new solution by integrating an old solution in the complex plane with regard to a parameter seems to have occurred independently to a Scotch mathematician (J. Dougal, Proceedings Edinburgh Math. Soc., 1901). For instance, he regards Bessel's function $J_n(kr)$ as a function of its order n, and integrates with regard to n. The Legendrian and other functions may be treated in the same way. New functions are thus obtained that satisfy various boundary conditions.

*Schlömlich's Zeitschrift, 1901, "Uber die Beugung der Röntgenstrahlen."

†Proc. London Math. Soc., 1899.

All that I have said illustrates the need there is for new forms of functional relationship. The more new functions we can invent the better; that is to say, functions with new and varied characteristic properties. We look to general function-theory to supply them. One never knows how soon they may find suitable use in some field of pure or applied mathematics. I said at the beginning that a number of physical problems are at a standstill for want of an appropriate mode of mathematical expression. In proof of this I may here quote the words of a few experts in different lines of work. Lord Rayleigh says:* "When the fixed boundary of a membrane is neither straight nor circular, the problem of determining its vibrations presents difficulties which in general could not be overcome without the introduction of functions not hitherto discussed or tabulated. A partial exception must be made in favor of an elliptic boundary."

I may note here that Mathieu† solved the problem of the elliptic membrane by transforming the differential equation to elliptic coordinates (λ, μ), so that one coordinate λ would be constant on the elliptic boundary, and then satisfying the equation by means of a product function

$$u = \varphi(\lambda) \cdot \psi(\mu),$$

making $\varphi(\lambda)$ vanish on the boundary. This method might seem promising for other boundaries; but Michell‡ has proved that the elliptic transformation is the only one that leads to an equation capable of being satisfied in the product form.

Lord Rayleigh says in another place:‖ "The problem of a vibrating rectangular plate is one of great difficulty, and has for the most part resisted attack. . . . The case where two opposite edges are free, while the other two are supported, has been discussed by Voigt."§

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*Theory of Sound, Vol. I, p. 343.

†Cours de physique mathématique, 1873, p. 122; Lionville. 1868.

‡Messenger of Math., 1890.

‖Theory of Sound, Vol. I, p. 372.

§Gottingen Nachrichten, 1893.

In connection with air vibrations he says:* "The investigation of the conductivity for various kinds of channels is an important part of the theory of resonators, but in all except a very few cases the accurate solution of the problem is beyond the power of existing mathematics."

Prof. E. L. Brown, in his Report on Hydro-dynamics presented to the Boston meeting, says: "No problem of discontinuous motion in three dimensions has yet been solved. The difficulty is one which can easily be appreciated. The theory of functions deals with a complex of the form $x + iy$, and this satisfies all problems in two dimensions. But little has been done with a vector in three dimensions. Perhaps the paper on potentials by Sommerfeld, in the Proceedings of the London Mathematical Society last year, may have some bearing on the problem; it is in any case worth serious study. The subject of discontinuous motion was set for the Adams' prize in 1895. A solution for a solid of revolution was asked for, and it was generally supposed that the circular disc would be the easiest to attempt. No solution was sent in. One prominent mathematician, who has aided considerably in the development of hydro-dynamics, mentioned that he had worked for six months and had obtained absolutely nothing. A magnificent reception, therefore, awaits the first solution."

Mr. Hayford† writes: "The most important tidal problem before us is that of determining the relation between the boundaries (bottoms and shores) and the modification produced by them on the tidal wave."

Professor Webster, in his Report on Recent Progress in Electricity and Magnetism presented to the Boston meeting, says: "The problem of electrical vibrations in a long spheroid is next to be attacked, and then perhaps on surfaces obtained by the revolution of the curves known as cyclides. The introduction of suitable curvilinear coordinates into the partial differential equations, will lead us in the case of the spheroid to new linear differential equations analogous to, but more

*Vol. II, p. 175.
†Science, Vol. VIII, 1898, p. 810.

complicated than Lamé's, and will necessitate the investigation of new functions and developments in series."

Dr. Webster also commends to the attention of pure mathematicians the various differential equations which are to be found in Heaviside's electrical papers; more especially the question of existence theorems.

I may mention here that Hilbert, in a recent volume of the Archiv,* suggests the question of proving an existence-theorem for the solution of any differential equation subject to assigned boundary conditions.

Even a partial solution of any one of these problems might open up new relationships and widen the intellectual horizon.

It is a hopeful sign that several resourceful pure mathematicians are turning their attention to such questions. Speaking at the Chicago Mathematical Congress in 1893, Professors Klein and Webster deplored the growing separation of the pure and physical branches of mathematics, and pointed out the great loss that would result to each of the divergent branches. The recent increased attention to mathematical history has enforced this opinion. The influence of Klein, Poincaré, Weber and others, has been helpful as a corrective on the continent of Europe. The British Universities have steadfastly treated mathematical physics as an organic part of mathematical discipline. The same statement could not be made with regard to all of the American Universities; but there are many signs of improvement. With a true historical instinct, this Section of the Association, and its ally, the American Mathematical Society, have exerted their influence for an organic union of the entire mathematical field. On the whole, the indications are that the separation which was so deplored ten years ago is now being arrested.†

I have spoken above of the discovery of new functional relations; but a useful work might also be done in completing the tabulation of old functions. The sister Association in England has set a good example in the work of its Committee

*Archiv der Math. und Phys., 1901, p. 228.

†This paragraph has been amplified since the address was read.

on Tables. The tables of elliptic integrals given by Legendre ought to be extended; and similar tables for the elliptic functions would be welcomed. The Neumann function needs tabulation, and several others might be mentioned. In many existing tables the interval of the argument should be made narrower. The familiar functions ought to be tabulated on the complex-plane. The labor could easily be divided up. I have myself made a beginning of this kind of work by computing the trigonometric and hyperbolic sine and cosine of $x + iy$ for values of x and y ranging separately from 0 to $\frac{1}{2}\pi$ at intervals of .1; it was published in Merriman and Woodward's Higher Mathematics, 1896, and I have already had my reward in the fact that one electrical engineer has told me that he has used this complex table in the application of vector-theory to alternating currents. In connection with the chart already referred to, Dr. Harris has given a convenient method of computing sn$z$, cn$z$, dn$z$. My friend, Dr. Virgil Snyder, has tabulated, under Professor Klein's direction, the Weierstrass sigma and zeta functions for the case $g_3 = 0$. The tables extend over nine parallelograms in the complex plane at intervals of one twenty-fourth of each period. They are now being published in Martin Schilling's Modell Verlag (Halle). The case $g_2 = 0$ will next be treated.

I have also drawn the attention of the Section on former occasions to the importance of tabulating certain fundamental integrals, so as to increase our stock of what are called "known functions," in terms of which many other integrals might be expressed. Among these were the two integrals

$$\int_0^\infty \log \sin x dx, \quad \int_0^\infty J_0(x) dx .$$

In all I have said regarding things that have been recently done, and other things that remain undone, it will be understood that I have confined myself to some of the matters that have been forced on my own attention. Many members of this Section, and of its esteemed affiliated Society, know of other recent advances, and other standing problems. Not to

go beyond the list of past officers that lies before me, I see the names of Eddy, Woodward, Waldo, and Ziwet, who could tell us of the new problems in Mechanics and Dynamics. Gibbs, Hyde, or Macfarlane could speak for Quaternions and Vector Analysis; Bigelow for the Mechanics of the Atmosphere; Hayford for Geodetic and Tidal Problems; Storey for Invariant Theory; Johnson for Differential Equations; Moore for Function Theory; Beman, Phillips or Strong for Geometry and Analysis; Miller for Group Theory. Then to speak for the various fields of astronomical work we have a noble band consisting of Newcomb, Young, Pickering, Langley, Hall, Harkness, Hough, Van Vleck, Eastman, Stone, Chandler, Doolittle, Comstock, Paul, Upton, Holden, Kershner, Frisby, Barnard, Hall, Frost and Lord.

It would seem that the work of the Section not only advances Science but tends to prolong life; for I find only two starred names in the list of officers since the Section was reorganized on its present basis twenty years ago.

Rogers and Ferrel have entered into the larger life, and their works do follow them, for they are being carried on to wider issues.

REPORTS READ.

A REPORT ON RECENT PROGRESS IN THE QUATERNION ANALYSIS.

BY ALEXANDER MACFARLANE.

[Read before Section A of the A. A. A. S., Pittsburg Meeting, July 2, 1902.]

In response to an invitation from the officers of the Section I have prepared a short report on the progress of the quaternion analysis. I have limited my remarks mainly to what has been done within the last twelve years or so, and in what I have written I have followed a geographical arrangement.

First of all let me direct your attention to what has been accomplished in Great Britain—the birthplace of the analysis.

For many years, owing to the eminence of Professor Tait, Edinburgh was the center of quaternion research. Occupying the chair of natural philosophy, he did not have the opportunity to teach the analysis to students, but he delivered several inspiring addresses on the subject to scientific societies composed of students and graduates. His students in quaternions were the readers of his *Elementary Treatise*, and these were of all ages and of all countries. His original papers were mostly contributed to the Royal Society of Edinburgh, and printed in either their *Transactions* or *Proceedings*. Most of their results are embodied in his *Treatise*, but the papers themselves have now been made more accessible, through the reprinting of all his Scientific Papers by the Cambridge University Press. The plan of publication provides for three volumes, of which the first appeared in 1898, the second in 1900, both edited by Tait himself; but the third must be posthumous, for in 1901 death ended the scientific labors of this eminent

mathematician a few months after he had resigned his appointment as professor. He had looked forward to devoting the leisure of his retirement to quaternion research, and two days before his death he covered a sheet of foolscap with a quaternion investigation. The third volume will contain a few later papers, a complete list of his writings, and an index to the Reprint. Out of the 133 papers printed in the volumes which have appeared, 41 are on the subject of quaternions; they are not printed together, but are scattered throughout the two volumes mainly in the order of their publication. Some of his first writings on the subject were strictly expository, and appeared as short articles in the *Messenger of Mathematics;* these have not been reprinted. Other contributions were applications of the quaternion analysis to physical problems, such as Fresnel's wave-surface, electro-dynamics, the potential of a closed circuit; they were written while he was a professor of mathematics at Belfast, and appeared in the *Quarterly Journal of Mathematics*. Their object is to apply the new analysis to give a more direct and logical treatment of the subjects mentioned; for this reason, rather than for any original results, they find a place at the beginning of the first volume. After Tait's translation to Edinburgh his quaternion researches were almost all published in the Transactions or Proceedings of the Royal Society of Edinburgh. The transactions contain the following memoirs: "On the Rotation of a Rigid Body about a Fixed Point," "On Green's and other Allied Theorems," "On Orthogonal Isothermal Surfaces," and "On Minding's Theorem. In the second of these memoirs and in several minor papers printed in the *Proceedings* he developed the subject of quaternion integration, which had been left undeveloped by Hamilton. Another class of reprints consists of articles on "Quaternions" and on "Hamilton," reprinted from the *Encyclopedia Britannica*, and of addresses delivered to Section A of the British Association and to the Physical Society of the University of Edinburgh, both of which contain an eloquent plea for quaternions. The numerous letters and papers which he wrote in controversy, are not included in these volumes with the exception of the paper "On the Intrinsic Nature of the

Quaternion Method," which he wrote in reply to Cayley's paper "Coordinates versus Quaternions"; and one of the letters which appeared in *Nature* in reply to Prof. Gibbs.

The controversy with Prof. Gibbs arose from the following remark made in the preface to the third edition of Tait's *Elementary Treatise:* "Even Prof. Willard Gibbs must be ranked as one of the retarders of quaternion progress, in virtue of his pamphlet on *Vector Analysis;* a sort of hermaphrodite monster, compounded of the notations of Hamilton and of Grassmann." Prof. Gibbs justified his departure from quaternionic usage by maintaining that whereas the scalar product and the vector product are each fundamental notions in vector analysis; the quaternion product, the quaternion quotient, and the quaternion in general are in comparison trivial and artificial. He admitted that the quaternion afforded a convenient notation for rotations, but added that rotations may also be represented by the linear vector function. In his second letter to *Nature*, May 28, 1891, Prof. Gibbs made a comparison of Hamilton's and Grassmann's systems as geometrical algebras, concluding thus: "We have then as geometrical algebras published in 1844 an algebra of vectors common to Hamilton and Grassmann, augmented on Hamilton's side by the quaternion and on Grassmann's by his algebra of points. This statement should be made with the reservation that the addition both of vectors and of points had been given by earlier writers."

Tait's principal reply, founded on an observation of Hamilton's, is that it was solely because Grassmann had not realized the conception of the quaternion whether as $\beta\alpha$ or as $\beta\alpha^{-1}$ that he felt those difficulties as to angles in space which he says, in the preface to the *Ausdehnungslehre* of 1844, he had not had leisure to overcome. On consulting the passage referred to, I find that Grassmann mentions that e^{α} expresses an angle operator, α denoting the angle in the geometrical sense; and that for a constant plane α can be analyzed into $a\sqrt{-1}$ where a is the circular measure of the angle. He observes further that the pure imaginary with the circular measure will not suffice for angles in space, and that there are

difficulties in the matter which he has not been able to surmount. Now the quaternion stripped of its tensor factor expresses this notion (but in a reduced form) by its sum of a scalar and a vector, the very combination which to Prof. Gibbs appears devoid of trigonometric import. Further, an improved analytic notation for a quaternion is derived from the exponential form looked at by Grassmann, by analyzing a into $a\sqrt{-1}\,a_0$ where a_0 denotes a unit axis. The only step which Grassmann failed to take was the introduction of the third element a_0 to denote the axis of the plane.

Mr. Heaviside, for the purpose of his electrical investigations, makes use of a vector-analysis which he rather facetiously describes as "Quaternions without the quaternions." This strikes one as a mathematical instance of the play of Hamlet with the character of Hamlet left out. As regards the notion of the quaternion he says (Electro-magnetic Theory, Vol. I, p. 136): "The quaternion and its laws were discovered by that extraordinary genius Sir W. Hamilton. A quaternion is neither a scalar nor a vector, but a sort of combination of both. It has no physical representatives, but is a highly abstract mathematical concept. It is the operator which turns one vector into another. It has a stretching faculty first, to make the one vector become as long as the other, and a rotating faculty to bring the one into parallelism with the other. Now in Quaternions the quaternion is the master, and lays down the law to the vector and scalar. Everything revolves round the quaternion. The laws of vector algebra themselves are established through quaternions, assisted by the imaginary $\sqrt{-1}$. But I am not sure that any one has ever quite understood this establishment. It is done in the second chapter of Tait's *Treatise*. I never understood it, but had to pass on. That the establishment is not demonstrative may be the reason of the important changes made therein in the third edition. But it is still undemonstrative to me, though much improved."

Mr. Heaviside is right in criticising the definition of a quaternion which says that it is the operator which turns one vector into another. Let q denote a quaternion and ρ a vector.

According to the principles of the quaternion analysis $q\rho$ is in general not a vector but a quaternion; but if q were really an operator $q\rho$ would be always a vector, having a directed component parallel to ρ as well as a directed component perpendicular to ρ. The truth is that in the quaternion analysis $q\rho$ is a product of two quaternions, the second factor differing from the first only in that its angle is not general but a quadrant. The physical representative of the quaternion is an angle in space associated with a multiplier. I agree with Mr. Heaviside in holding that the establishment of the laws of Quaternions given in the second chapter of Tait's *Treatise* is not demonstrative. There i j k are used to denote quadrants round a mutually perpendicular system of axes, and $\mathbf{i}$ $\mathbf{j}$ $\mathbf{k}$ to denote these axes themselves; ij is the product of two angles taking j first, and it is true that $ij=k$; $i\mathbf{j}$ denotes i operating on $\mathbf{j}$ and it is true that $i\mathbf{j}=\mathbf{k}$. To complete the parallelism it is necessary that ii and $i\mathbf{i}$ should give the same result. The product of two quadrantal angles round i is i^π, which for certain purposes may be reduced to -1; but i operating on $\mathbf{i}$ leaves it $\mathbf{i}$. The parallelism breaks down. Are we to be asked to believe that in ij i is an operator and j an operand, but that in ii both symbols are operators?

In 1892 Prof. Knott contributed to the Royal Society of Edinburgh a paper entitled "Recent Innovations in Vector Theory," in which he essays to reply to the criticisms of "a clique of vector analysts who refuse to admit the quaternion to the glorious company of vectors." The alleged clique was said to comprise Gibbs and Heaviside and myself on account of a paper which I read before the Washington meeting of this Association. This was surprising news to me, for at the time of reading the paper I had not seen Heaviside's contributions to vector-analysis, and in the paper itself I maintain that vector-analysis is merely complimentary to the versor (or quaternion) analysis. Is it scientific to found vector-analysis on a rather arbitrary and detached selection of so-called "definitions" as is done by the mathematicians mentioned? What is a definition but the statement of the meaning of a term or symbol? Besides definitions,

axioms or fundamental rules are required. If we seek the product functions of vectors according to the rules

$$i^2 = 1 \qquad j^2 = 1 \qquad k^2 = 1 \tag{1}$$

$$ij = k \qquad jk = i \qquad ki = j \tag{2}$$

$$ji = -k \quad kj = -i \quad ik = -j \tag{3}$$

we obtain the exact functions which occur so frequently in applied mathematics; but when we form the product functions of three or more vectors, we obtain results which are different according to the manner of association of the factors. To make the results associative it is necessary to introduce the $\sqrt{-1}$ as a multiplier on the right-hand side of the equations of the second and third class. It seems to me that the logical relation of a strictly vector-analysis to the strictly versor analysis is still a subject for further investigation.

In the paper referred to, and in his letters to *Nature*, Dr. Knott parades the old fallacy mentioned above. He says that in vector-analysis it is impossible to get rid of the versorial character of the multiplier vector in such a product as $ij = k$. Whether that be true or not it is certainly impossible in quaternion algebra to get rid of the versorial character of the multiplicand in the same expression. Prof. Knott gets rid of it in ij but not in ii.

The main contention of Cayley's paper is that, whereas coordinates are applicable to the whole science of geometry and are the natural and appropriate basis and method in the science, Quaternions is a particular and very artificial method for treating such parts of the science of three-dimensional geometry as are most naturally discussed by means of the rectangular coordinates x, y, z. To this Tait replied that the Quaternion invented by Hamilton in 1843 and the Quaternion afterwards discovered by Hamilton were very different, in that the former was based on a system of imaginaries i, j, k defined by the equations $i^2 = j^2 = k^2 = ijk = -1$, whereas the latter is a space reality altogether independent of and antecedent to i, j, k or x, y, z. The process of development was from the analytic expression to the synthetic expression.

It may be remarked that the exponential function furnishes the most natural analytical expression for a quaternion, and that therefore Cayley's view of the province of the method is altogether too limited. But the transcendental functions of vectors in space are precisely those which Hamilton (see *Elements*, Art. 333) and Tait (see preface to 2d edition of *Treatise*) left undeveloped.

Dr. Peddie has recently contributed to the Proceedings of the Royal Society of Edinburgh a paper "On the Use of Quaternions in the Theory of Screws."

Turning to Dublin we remark that so much has been accomplished there within recent years that it is safe to say that the quaternionic mantle has returned to Dublin, and is now worn by the occupant of Hamilton's chair—Prof. C. J. Joly. Dunsink Observatory is not only the scene where Sir W. R. Hamilton developed the quaternion method; it is likewise the scene where Sir Robert Ball investigated the Theory of Screws. What other spot is there in the British Isles so interesting in the history of modern mathematics?

Prof. Joly has edited for the Board of Trinity College, Dublin, a new edition of the *Principia* of the quaternion analysis—Hamilton's *Elements*. The original edition had the form of one huge octavo volume with a great quantity of small print; the new edition appears in two handsome quarto volumes clothed in typography which leaves nothing to be desired. The editor has preserved faithfully the original text, which he found on examination to be remarkably free from errata; to facilitate the work of the student he has added notes, increased the cross references, added an index, and pointed out more minutely the order of reading for a first course. The first of the volumes appeared in 1899 and the second in 1901. A series of more elaborate notes, printed together in an appendix, treat of "Quaternion determinants," a subject first investigated by Cayley; "Miscellaneous properties of two linear vector functions;" "The strain function;" "The specification of linear vector functions;" "Invariants of linear vector functions;" "The system of linear vector functions $\varphi + t\cdot$;" "The general linear transformation in space;" "The theory of

screws" following the researches of Sir R. S. Ball; "Finite displacements;" "The kinematical treatment of curves;" "The kinematical treatment of surfaces;" "Systems of rays," and "Hamilton's operator ∇."

While engaged on this editorial work he contributed to the Royal Irish Academy several papers which have been printed in the *Proceedings*, their titles being "Vector Expressions for Curves;" "The Associative Algebra Applicable to Hyper-space;" "The Homographic Divisions of Planes, Spheres, and Space;" "Astatics and Quaternion Functions;" "Some Applications of Hamilton's Operator ∇ in the Calculus of Variations;" and "The Place of the *Ausdehnungslehre* in the General Associative Algebra of the Quaternion Type." In 1877 Grassmann in his paper "Der Ort der Hamilton'schen Quaternionen in der Ausdehnungslehre" (Mathematische Annalen XII, 375-386), aimed at showing that the method of Quaternions was contained within the four corners of the *Ausdehnungslehre*. Prof. Joly attempts to establish what may be called the converse relation. He considers an algebra whose fundamental laws are $i_s^2 = -1$ and $i_s i_t + i_t i_s = 0$, which is quaternionic on account of the first law, but a generalized quaternion algebra because $ij = k$ no longer holds; and he concludes that the *Ausdehnungslehre* as adapted to a space of n-dimensions may be regarded as a part of the associative algebra of $n + 1$ dimensions limited by more or less arbitrary restrictions. More recently he has published in the *Transactions* of the same academy a series of highly original memoirs, which constitute the most recent development of the quaternion analysis. They are entitled "Properties of the General Congruency of Curves," "The Interpretation of a Quaternion as a Point Symbol," "Quaternion Arrays." In the last two memoirs a quaternion is interpreted as a point-symbol by taking the scalar component to denote the mass, and the vector component to denote the mass-point; the addition of quaternions then gives the sum of the masses and the geometrical sum of the mass-points. He makes use of the following notation, due to Hamilton*

*Elements, Bk. III, Chap. 2, Art. 365.

$$(ab) = bSa - aSb \qquad [ab] = VVaVb$$

$$abc) = Sa[bc] \quad [abc] = (abc) + [cb]\,Sa + [ac]\,Sb + [ba]\,Sc$$

$$(abcd) = Sa\,[bcd]\,;$$

and the following relations, also due to Hamilton,

$$a(bcde) + b(cdea) + c(deab) + d(eabc) + e(abcd) = 0$$

and

$$e\,(abcd) = [bcd]\,Sae - [acd]\,Sbe + [abd]\,See - [abc]\,Sde.$$

In these functions the symbols $a\ b\ c\ d\ e$ may be transposed as in determinants, provided that, as in determinants, the sign be changed at each step in the transposition. In this way Prof. Joly develops the quaternion analysis so as to embrace the point-analysis which Prof. Gibbs indicated as peculiar to the Ausdehnungslehre. In space analysis there is room for all the ideas both of Hamilton and Grassmann, and the reduction of their ideas to one system and notation is greatly to be desired.

The contribution of Cambridge to the quaternion analysis within the period considered consists principally of the works of Whitehead and McAulay. In his investigation of the Theory of Screws, Sir Robert Ball found the analysis of Grassmann more directly applicable. In 1898 Mr. Whitehead began the publication of "A Treatise on Universal Algebra," the purpose of which is to present a thorough investigation of the various systems of Symbolic Reasoning allied to ordinary algebra, the chief examples being Hamilton's Quaternions, Grassmann's Calculus of Extension, and Boole's Symbolic Logic. The idea of a generalized conception of space is made prominent in the belief that the properties and operations involved in it can be made to form a uniform method of interpretation of the various algebras. The first volume takes up Symbolic Logic and the *Ausdehnungslehre*, and the second will take up Quaternions and the Theory of Matrices. In the preface the author remarks: "The subject-matter of this volume is not concerned with Quaternions; accordingly it is the more

necessary to mention in this preface that Hamilton must be regarded as a founder of the science of Universal Algebra. He and De Morgan were the first to express quite clearly the general possibilities of algebraic symbolism." In my opinion had Mr. Whitehead not included Symbolic Logic in the field considered, he would be dealing with a much more homogeneous subject. The search after general laws which will apply to both Symbolic Logic and to space-analysis is rather hopeless; anyhow space-analysis is a wide enough subject in itself. Is there any such thing as Universal Algebra? According to Mr. Whitehead the general principles of universal algebra are as follows: Addition follows the commutative and associative laws, viz, $a+b=b+a$ and $(a+b)+c=a+(b+c)$. Multiplication follows the distributive law, viz, $a(c+d)=ac+ad$ and $(a+b)c=ac+bc$; but it does not necessarily follow the commutative and associative laws; that is, $ab=ba$ and $(ab)c=a(bc)$ are laws of special branches only. Now there is a logical inconsistency in such a system of fundamental laws; for on the one hand the principle of commutation is always applied to the addition of indices, but on the other hand the addition of indices cannot be commutative when the factors of which they are the indices are not commutative.

While a student at Cambridge University, Mr. Alexander McAulay prepared (1887) in competition for the Smith's Prizes, an essay on "Quaternions as a Practical Instrument of Physical Research," which was published in 1893 as a separate volume under the title "Utility of Quaternions in Physics." After graduation he received an appointment in Australia, where, in 1892, he read before the Australasian Association for the Advancement of Science a paper having the former title, which was published in the *Philosophical Magazine* for June, 1892. In 1890 he contributed to the Royal Society of Edinburgh a paper containing the more original part of his essay under the title of "Proposed Extension of the Powers of Quaternion Differentiation." The main point contended for is that the operator ∇ and its operand or operands may have any relative positions in a term which are convenient, the connection between them being indicated in the usual way by

suffixes. Professor Tait conceded that ∇ and its operand may be separated by other symbols provided that the ∇ is to the left of the operand. Prof. McAulay holds that the said proviso is an unnecessary and inconvenient restriction. He also introduced several auxiliary symbols applicable to quaternion differentiation.

The main thesis of the essay is that the method of Quaternions requires a slight development in order to be readily applicable to physical questions, and that the necessary development is supplied by the proposed extension of the powers of quaternion differentiation. The mode of proof followed is to apply the more developed method to the treatment of various physical problems; and he subsequently applied it in a memoir on "The Mathematical Theory of Electromagnetism," published in the *Philosophical Transactions* for 1892.

At the end of 1895 Prof. McAulay communicated to the Royal Society of London an elaborate paper, entitled, "Octonions, A Development of Clifford's Bi-quaternions." It was read in abstract and, on account of its being more a treatise than a paper, it was printed (1898) in book form at the expense of the Royal Society and the Cambridge Press Syndicate. The author prefers the new name "Octonions" in preference to "bi-quaternions," because he thinks it desirable that the latter name should be left to denote that to which Hamilton applied it, namely, the sum of two quaternions one of which is affected by $\sqrt{-1}$. As a matter of fact there are spherical quaternions and hyperbolic quaternions, and the sum of a spherical and a hyperbolic quaternion is a complex quaternion —the bi-quaternion of Hamilton. On the other hand the "Octonion" is defined as follows: Let q and r denote quaternions whose axes pass through a common point O, and let ω denote an ordinary scalar which has the special property that $\omega^2 = 0$; then the octonion Q is such that

$$Q = q + \omega r.$$

This work of Prof. McAulay is the result of the study of Quaternions combined with the study of Ball's Theory of Screws and Grassmann's *Ausdehnungslehre*.

In 1889 Rev. M. M. U. Wilkinson, contributed to the Royal Society of Edinburgh a paper "On the Scalar Relations Connecting Six Vectors." He gives the general theory of the relations connecting vectors, and discusses minutely the case of six vectors.

In France, M. Gaston Combebiac, capitaine du génie, has recently produced a number of valuable investigations based on the quaternion analysis. He first took up the subject of bi-quaternions, and communicated a paper to the Mathematical Society of France "Sur l'application du calcul des biquaternions à la géometrie plane" (Bulletin, tome XXVI). From that he passed to a new development of the quaternion analysis which he calls "Triquaternions," and which he has made the subject of his doctor's thesis, presented to the Faculty of Science of the University of Paris. The object of the investigation is to establish a geometrical analysis independent of every system of reference. The methods of the *Ausdehnungslehre* do not, the writer says, satisfy the idea, because they are not subject to an absolute system of rules; the quaternion method, on the other hand, constitutes a true geometrical analysis, being subject to uniform rules. But the quaternion analysis, although dispensing with axes, retains the idea of an origin, which allows some elements foreign to the question to remain in the formulas. While the biquaternion is a complex quaternion of the kind considered by Clifford and McAulay, namely, $q + \omega q$, where ω is a scalar but such that $\omega^2 = 0$, the triquaternion is a complex quaternion of the form

$$q + \omega q_1 + \mu q_2$$

in which μ is another scalar, but subject to the conditions $\mu^2 = 1$ $\mu\omega = -\omega\mu = \omega$, and in which q, q_1 and q_2 denote quaternions. While the quaternion applies to rotations round a fixed point, and the biquaternion to displacements without deformation, the triquaternion applies to point transformations of space by similitude.

In recent years the quaternion analysis has engaged the attention of a number of mathematicians in Holland. Dr. P. Molenbroek has published an excellent treatise in the Ger-

man language, consisting of two parts, "Theorie der Quaternionen" (1891) and "Anwendung der Quaternionen auf die Geometrie" (1893). In the few places where he enters on original development of the analysis he is not particularly fortunate; for instance in his theory of $\sqrt{-1}$. Let α denote a vector, then in the expression $\sqrt{-1}\alpha$ he considers $\sqrt{-1}$ as denoting a quadrantal version round any axis perpendicular to α. In this way he gives to $\sqrt{-1}$ a meaning dependent upon the particular vector to which it is attached, whereas its meaning is independent of such symbol. The correct view is that just as when x denotes a number $\sqrt{-1}x$ denotes an imaginary number; so when α denotes a vector, $\sqrt{-1}\alpha$ denotes an imaginary vector; from which it follows that $\sqrt{-1}$ never indicates direction in space, but is entirely scalar in character. This coincides with the view finally held by Hamilton; but many writers, including Dr. Molenbroek, have not reached this stage in the development of their ideas.

In 1890–'91, Dr. Th. B. van Wettum published a series of papers in *Nieuw Archief voor Wiskunde*, which he afterwards published as a pamphlet in the English language under the name of "Researches on Matrices and Quaternions." The author aims at giving a definite algebraic form to the quaternion as a "real in geometry," by means of the matrix; and at showing how the subject of Hamilton's calculus may be treated without any imaginaries merely with the help of the matrical symbol. He criticises the identification of a quaternion with a dual matrix of the second order previously made by Cayley and others, because it involves the algebraic imaginary. As regards differentiation he says: "We purposely do not enter upon differentials as it is a very difficult question whether the differential calculus of more dimensional quantities or symbols has a meaning at all." He objects to imaginaries and to spaces of more than three dimensions as tending to undermine the throne properly occupied by the "matrix scientiarum."

The researches of Dr. van Wettum were reviewed by Dr. L. van Elfrinkhof in several papers printed in the same journal. In 1892 appeared "Opmerkingen naar aanleiding der ver-

handeligen over quaternionen matrices van den Herr Th. B. van Wettum;" and in 1894 "Draaiings-matrices en quaternions." He points out that the operator expressing a conical rotation through an angle θ which is twice the angle of the quaternion $q^{1/2}$ is expressed by $q^{1/2}(\ )q^{-1/2}$; and not by $q(\ )$, unless in the special case of the operand being perpendicular to the axis. The former operator, $q^{1/2}(\ )q^{-1/2}$, can be expressed by means of a matrix; whereas the latter operator $q(\ )$ cannot in general, and therefore the quaternion must be a more general symbol than the matrix of van Wettum.

Dr. van Elfrinkhof has also contributed to the same journal papers entitled "Der vergelijking $V\rho\varphi\rho = 0$;" "De oplossing van lineaire vector-vergelijkingen in bijzondere gevallen;" and "Eene eigenschap van de orthojonale substitutie van de vierde orde."

In 1898 Mr. W. A. Wythoff prepared as a thesis for doctor of science at the University of Amsterdam "De biquaternion als Bewerking in de Ruimte van vier Afmetingen." He had read the previous researches of Clifford and McAulay.

In Germany most of the contributions to space-analysis have been based on Grassmann's methods. Dr. Paul Glan, the translator of Hamilton's *Elements*, contributed to the *Annalen der Physik und Chemie* for the years 1895-'6 a series of six papers entitled "Theoretische Untersuchungen über elastische Körper," in which he applies the methods of the quaternion calculus.

Prof. Heinrich Burkhardt contributed to the *Mathematische Annalen* for 1893 a paper "Ueber Functionen von Vectorgrössen, welche selbst wieder Vectorgrössen sind," in which he treats of the rational integral vector functions of vectors as given by the quaternion calculus as well as those given by Grassmann's method. To the Deutsche Mathematiker Vereinigung he contributed in 1896 (vol. V of Yahresbericht) a paper entitled "Ueber Vector-analysis." He cites as the fundamental principle of vector-analysis that reckoning is to be made not by means of coordinates but by means of the quantities themselves. He observes that in the algebra of the plane this condition is satisfied by the addition of the coplanar vectors,

but not by their multiplication, for the reason, I suppose, that in their multiplication the concept of an initial line is required. The reply to this objection is that the algebra of the plane is not an algebra of coplanar vectors, but of coaxial quaternions in the multiplication of which the idea of an initial line is not required. Prof. Burkhardt remarks that a problem which involves transcendental functions can never be made algebraic by any species of analysis; that, indeed, new results might be hoped for from a systematic theory of the transcendental functions of vectors, but that scarce a beginning has been made in that direction. That is only too true. It has long seemed to me that one of the weak points in Hamilton's *Elements* is his treatment in Chapter I, Book III, of the transcendental functions of quaternions; in fact, he restricts the investigation to coaxial quaternions, commonly called coplanar vectors. In Tait's *Treatise* likewise there is no treatment of quaternion exponentials and logarithms, and the related sines and cosines.

In the same paper Prof. Burkhardt falls into the fallacy of confounding the quaternion with an operation which combines a rotation with a uniform expansion; and as a consequence he concludes that the quaternion analysis is a very special method, very far from satisfying the conditions of a general method such as it has been proclaimed to be by Hamilton and his followers. The conclusion is no doubt true of the rotation quaternion to which he reduces the Hamiltonian, but it is not true of the true Hamiltonian quaternion. Consider for a moment that, corresponding to plane trigonometry we have an analytical plane trigonometry which is indeed the algebra of the plane—a general method according to Prof. Burkhardt himself. We have likewise spherical trigonometry; corresponding to it there ought to be an analytical spherical trigonometry involving algebraic and transcendental functions of angles in space. If such exists, is it not a general method? It must be so, for it includes analytical plane trigonometry as a particular case. The elements of such method are contained in Hamilton's quaternions, and we have shown that Grassmann was alive to its importance.

The same restricted view of a quaternion is made the basis of a digression on quaternions by Prof. Klein and Dr. Sommerfeld in Heft I of their treatise "Ueber die Theorie des Kreisels." According to these mathematicians the quaternion is simply a "Drehstreckung;" and they deduce that the quaternion method will be in place, when it is desired to have a convenient algorithm for the combination of rotations and dilatations. Upon this theory of quaternions they make a claim in behalf of Gauss to at least a share in their invention. One of the last of Prof. Tait's papers was on the subject of this claim, and his conclusion is as follows: "Unfortunately for such a conclusion a Drehstreckung is not a Hamiltonian quaternion at all, but a totally different kind of concept. It is obviously only a very limited form of linear and vector operator (kinematically a strain) depending upon four constants instead of the usual nine; and might, perhaps, but on that account solely, have been designated by the name quaternion had the name not been already worthily bestowed."

What then is a quaternion according to Professor Tait? In the paper quoted he says that a quaternion expresses the relation of one vector to another or supplies the factor required to convert one into the other; when applied to any vector in or parallel to its plane, it turns the vector through a given angle in or parallel to that plane, and alters its length in a given ratio. He adds, "Obviously, when the quaternion is applied to a vector which is not perpendicular to its plane, the result is a new quaternion not a vector." This "obviously" is anything but obvious. Clifford held that a quaternion applied to a vector not in its plane (Collected Papers, p. 388) gave an entirely imaginary or uninterpretable result. The true answer is that in quaternion multiplication we always have the composition of angles; that the supposed vector is a quadrantal angle with, in general, a multiplier; if the axis of the quadrantal quaternion is perpendicular to the axis of the other, the result of the composition is a quadrantal quaternion; for if the second side of the spherical triangle is a quadrant and at right angles to the first side, then the third side is also a quadrant; but if the quadrantal quaternion is not at

right angles to the first, the result of the composition is not in general a quadrantal quaternion; for under the circumstances the third side of the spherical triangle will not be a quadrant. Hence quaternion multiplication is always the composition of spherical angles.

In Austria the quaternion analysis has been cultivated by Professors Merten and Studnicka. The former mathematician published in 1888 "Anwendung der Hamilton'schen Quaternionen auf die Statik" as a program of the State gymnasium at Saaz. The latter mathematician has published numerous papers in the Prag *Berichte* and in the mathematical journal *Casopis* which is printed in the Bohemian language.

As regards the progress of the quaternion analysis in Japan, it may be said, borrowing the language of Cl rk Maxwell with reference to physical research in that country, that by the activity of the Japanese quaternionists—Kimura, Hakii, Kumamoto—the center of quaternion progress has been removed several degrees eastward. The prime founder of the international association for the promotion of quaternion and allied analysis was Prof. Kimura; and in no country has the association received more active support than in Japan. The Japanese are not likely to import "a high-sounding phrase destitute of meaning," or "an aberration of the human intellect;" hence their activity in quaternion research is a sterling tribute to the value of Hamilton's invention.

Prof. Kimura published in the *Annals of Mathematics* for 1895 a memoir "On the Nabla of Quaternions," in which he treats not merely of the Hamiltonian nabla

$$_{\rho}\nabla = i\frac{\partial}{\partial x} + j\frac{\partial}{\partial y} + k\frac{\partial}{\partial z};$$

but of a generalized form, namely, the quaternion nabla

$$_{q}\nabla = \frac{\partial}{\partial t} + i\frac{\partial}{\partial x} + j\frac{\partial}{\partial y} + k\frac{\partial}{\partial z},$$

which was suggested to him by the study of McAulay's extension of the powers of quaternion differentiation.

Profs. Kimura and Hakii have published in the Japanese language the first part of "Lectures on Quaternions," which, so far as I can make out from the figures and mathematical notation, gives evidence of thorough and lucid treatment.

Within the period of our review there has been considerable activity in America. In 1898 Prof. G. A. Miller contributed a paper "On the Quaternion Group" to the American Philosophical Society, and in 1899 Prof. J. M. Pierce contributed a paper on "Quaternion Determinants" to the American Mathematical Society. Prof. C. W. Comstock took for the subject of his doctor's thesis at Cornell University "The Application of Quaternions to the Analysis of Internal Stress," which has since been published as a pamphlet. At the Springfield meeting of this Association Prof. J. B. Shaw read a paper entitled "Development of Some Useful Quaternion Expressions with Application to Geometry of Three and Four Dimensions." I have seen only the abstract of the paper printed in the *Proceedings* of the Association; but from it I gather that the paper had a similar scope to Prof. Joly's paper on the interpretation of the quaternion as a point-symbol; for both start out from the same formulæ in Hamilton's *Elements*. At the Buffalo meeting Prof Shaw read a paper on "Sedenions," by which term he means the most general linear quaternion function of a quaternion; and he so names it, because it involves in general sixteen constants, whereas the nonion or general linear and vector function of a vector involves nine.

Prof. Hathaway in 1896 accomplished the task of reducing the exposition of the elements of quaternions to the form and dimensions of a "Primer"— a task which the inventor could never have accomplished. The book is logically written, and the method is placed on such a basis that students can readily grasp its essential features. Prof. Hathaway makes prominent the distinction between the simple vector and Hamilton's quadrantal versor, calling the former after Clifford a "step," and the latter a "vector." The choice of terms to mark the distinction is not very happy, for usage has now applied "vector" to the former of the two ideas. If the quadrantal versor is a vector at all, it is an imaginary vector. To empha-

size the fact that the quaternion is a natural extension of the idea of number and subject to ordinary principles of geometrical representation, Prof. Hathaway frequently speaks of a quaternion as a number; for instance, he says, "The number r rotated through 2 arc q is the number qrq^{-1}." A quaternion is no doubt a complex number; but it is a geometrical complex number—one which has an axis in space; consequently, it seems to me to be inappropriate to speak of it under the term number without qualification. To rotate a number or even a complex number has no meaning, unless the said complex number has an axis in space.

Prof. Hathaway has also written a series of quaternionic papers. Some of these are printed in the Proceedings of the Indiana Academy of Science, the most important one being on "Alternate Processes." Others were contributed to the American Mathematical Society; and in their Transactions for 1902 there is a very original memoir on "Quaternion Space," by which is meant space of four dimensions, and the object of the paper is to investigate the properties of this space by the aid of the quaternion analysis.

In the second volume of his *Synopsis der hoeheren Mathematik*, published in 1894, Prof. Hagen, of Washington, devotes a chapter to "Die Ausdehnungslehre," by which term he means not Grassmann's analysis only but what is commonly expressed in English by "space-analysis." He takes the works of Argand, Moebius, Hamilton and Grassmann as the foundations of the subject; discusses the researches of later writers; and gives a clear, logical and unifying synopsis of what had been established at the time of writing. The chapter in question contains much historical information, and is specially valuable as the result of impartial study of rival systems by one eminently fitted for the task of logical unification.

At the Washington meeting of this Association I read a lengthy paper on "The Principles of the Algebra of Physics," which was printed in full in the *Proceedings*. I viewed the algebra of space (more generally the algebra of physics) as consisting of two complimentary parts—the algebra of vectors and the algebra of versors or, more generally, quaternions. The fundamental rules for the former were taken to be

$$i^2 = 1 \qquad j^2 = 1 \qquad k^2 = 1 \tag{1}$$

$$ij = k \qquad jk = i \qquad ki = j \tag{2}$$

$$ji = -k \qquad kj = -i \qquad ik = -j. \tag{3}$$

The fundamental rules for the latter are the same as the above with the introduction of a minus sign in every case; not only in the square set, No. 1, but in the two product sets Nos. 2 and 3. It is commonly supposed that the difference is only in the square rules, for example $i^2 = -1$ instead of $i^2 = 1$; the difference in the case of the product rules is masked by the fact that Hamilton takes the order from right to left instead of the order of writing. I showed that the products of the vector multiplication do not satisfy the associative law; and in a subsequent paper I showed that they can be modified so as to do so by introducing $\sqrt{-1}$ on the right side of each of the product rules; for example, $ij = \sqrt{-1}k$ instead of $ij = k$. With this modification, the difference is reduced to that between real and imaginary vectors.

Looking at the importance of the exponential function in analytical plane trigonometry, I was led to consider that a generalized form of the exponential function is the best analytical expression for a quaternion; that is $re^{\theta\sqrt{-1}\alpha}$ where r denotes the tensor, θ the angle, and α the axis of the quaternion is a more direct expression than $w + ix + jy + kz$; for the latter is only a kind of reduced expression for the quaternion; just as $\cos\theta + \sqrt{-1}\sin\theta$ is a kind of reduced expression for $e^{\theta\sqrt{-1}}$. In this way I was led to consider whether the exponential law is true of these generalized exponentials, or is not true as Hamilton believed; that is, whether $e^\rho e^\sigma = e^{\rho+\sigma}$ where ρ and σ denote Hamiltonian or imaginary vectors. As the factors e^ρ and e^σ in $e^\rho e^\sigma$ are not commutative, the sum $\rho + \sigma$ in the supposed equivalent expression $e^{\rho+\sigma}$ cannot be commutative; hence the square $(\rho + \sigma)^2$ must be formed preserving the order of ρ prior to σ; this gives $\rho^2 + 2\rho\sigma + \sigma^2$ for the square. Hamilton, by treating $\rho + \sigma$ as the sum of ordinary commutative vectors, got $(\rho + \sigma)^2 = \rho^2 + \rho\sigma + \sigma\rho + \sigma^2$; and consequently found

$$e^\rho e^\sigma \text{ not } = e^{\rho+\sigma}\,;$$

But if the powers of $\rho + \sigma$ are formed preserving the order of ρ prior to σ, we get

$$e^{\rho}e^{\sigma} = e^{\rho+\sigma}.$$

From this as a starting point the Binomial Theorem and the Multimonial Theorem for sums of vector logarithms are developed; and the development of the transcendental functions of vectors becomes plain and straightforward. The exponential theorem which I established in my paper on "The Fundamental Theorems of Analysis Generalized for Space" has not been disproved, but it has been styled "quasi-exponential." There is however no "quasi" about it; for $e^{\sigma}e^{\rho}e^{-\sigma}$ when developed into powers of $\sigma + \rho - \sigma$ according to it gives e^{ρ} turned round the axis of e^{σ} by twice the angle of e^{σ}. But if $\sigma + \rho - \sigma$ is treated, after Hamilton's fashion, as merely a sum of vectors, it manifestly reduces to ρ; from which it would follow that $e^{\sigma}e^{\rho}e^{-\sigma} = e^{\rho}$. Hence Hamilton's exponential theorem is not even "quasi," it is erroneous. The exponential theorem gives the true expression for the cosine and sine of the diplanar quaternions.

In several subsequent papers I have treated of the hyperbolic complex quantity in the plane. Corresponding to the analysis for coaxial spherical quaternions there is an analysis for coaxial hyperbolic quaternions. The exponential expression for a quaternion shows at once that the Hamiltonian quaternion is spherical in its nature, and therefore there must be a corresponding hyperbolic quaternion. In a paper on elliptic and hyperbolic analysis I take up these more general quaternions.

The development of the transcendental functions has an important bearing on the subject of differentiation, which I have considered in a paper on "Vector Differentiation," contributed to the Philosophical Society of Washington, and in a paper on "Differentiation in the Quaternion Analysis," printed in the Proceedings of the Royal Irish Academy. I there consider the problem of finding the nabla for functions expressed in terms of the spherical coordinates r, θ, φ, and the deduction from it by direct processes of the expression for ∇^2. The

problem is still further considered in a paper on "Curvilinear Coordinates," read before the Paris Congress of Mathematicians.

In 1901 Prof. Baker read a paper before the Royal Society of Canada on "The Principles at the Base of the Quaternion Analysis." For a subject which is so intensely geometrical the writer makes too much use of definition and convention. In $ki = j$ he regards k as an operator and i and j as vectors; to get over the difficulty about ii he brings in a new definition or convention that it shall be -1, regardless of the fact that according to the first definition or convention it is i. If the analysis is to be based upon conventions, these conventions must not be contradictory of one another. The truth is the theory that in $\alpha\beta$ the first factor α is a quadrantal versor and the second β a vector is at the bottom of all the obscurities which have beset the quaternion analysis; in $\alpha\beta\gamma$ we are asked to believe that β may be a quadrantal versor or a vector according to the mode of association. The theory also led to the change of order from that of writing; and how deep the fallacy is may be seen from the opposition which Prof. Tait made to the development proposed by Mr. McAulay.

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[See page 305.]

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ADDRESS

BY

D. B. BRACE,

VICE-PRESIDENT AND CHAIRMAN OF SECTION B FOR 1901.

THE GROUP-VELOCITY AND THE WAVE-VELOCITY OF LIGHT.

Although the determination of the important constant of nature—the velocity of light—has occupied the attention of scientists from the time of Galileo, and while astronomical and terrestrial methods have been so carefully refined that individual observers have obtained values differing by less than one part in 3,000, it is a significant fact that no terrestrial method thus far used gives the absolute velocity of light under all conditions. If a group of periodic disturbances is radiated out into any medium the velocity of the individual elements will in general be different from that of the mean of the group. Only in the one instance, the propagation in vacuo, is it likely that these two velocities are the same; and here physical methods thus far have not put the question to a test. In the case of ponderable media important data are to be expected. The astronomical method used by Römer in 1675 and founded on the observation of the eclipse of Jupiter's satellites gives the so-called group-velocity of light in vacuo. The observation of the fixed stars discovered by Bradley in 1727 gives the wave-velocity in the medium within the observing telescope. This is the only method thus far used which gives the absolute velocity of light.

The uncertainty in the constant of aberration and the errors in the observations of Jupiter's satellites render these methods unsuited for the comparison of the two velocities. We owe per-

haps to Arago more than to any other person a solution of this problem of the velocity of light. In 1838 he submitted to the French Academy the plan of an experiment for solving directly and definitely the question—which was being much debated—whether light was a corpuscular emission from radiant bodies or simply the result of the vibrations of a very rare medium. The method was simply an adaptation of the rotating mirror ingeniously devised by Wheatstone for determining the velocity of propagation of electricity in a wire. It was not till 1850, however, that this method, in the hands of Foucault, was actually put to the test of determining this constant. In the preceding year, however, Fizeau had published the results of his experiments by means of a toothed wheel. These were the first observations made on the velocity of light at the earth's surface. The first idea of this method seems to have originated with the Abbé Laborde who communicated it to Arago some years before. Upon these two principles is based our entire knowledge by terrestrial methods of this constant. On the one side we have the refinement and modifications of the toothed wheel as used by Cornu in France and Young and Forbes in England and on the other the very accurate results of Michelson in his classic experiments and those of Newcomb with his highly refined pototachometer in this country. It may well be questioned whether much greater certainty in data is attainable than those which the late lamented French savant and illustrious physicist Cornu has left as one of his most brilliant legacies to science. Nor can we hope for any considerable refinement in the determinations by the other method as used in this country, and which have already given the most surprising agreement and warrants us in taking the value obtained as the most accurate of all. Notwithstanding the elaborate execution of these experiments serious discrepancies exist between the results of the two methods. The latest discussion by Cornu of his own results gives as the most probable value of this constant 300,130 meters, while the values of Michelson and of Newcomb are 299,853 and 299,810, respectively. This makes the error of the results by the two methods ten times the error between

those of the same method.. This difference has given rise to the impression that in the one or the other or in both methods a systematic error exists and the discussions and corrections made by different critics have left the problem in a somewhat uncertain state. The relation of these determinations to the absolute velocity in air at the earth, and to the absolute terrestrial velocity in vacuo and the possible difference from the velocity in space, renders the problem of great interest and importance in this aspect alone. The famous theory of Weber of moving charges to explain the action of electric currents, while incompatible with the principle of the conservation of energy, has done much to enlarge our views of the origin of electrodynamic phenomena and to establish a comprehensive theory of present phenomena. The brilliant experiment of Rowland as a natural sequence of Weber's theory demonstrated the electromagnetic reaction of a moving charge and showed further that if the velocity were that of light the mechanical reaction would be approximately that calculated from theory by using the value of the light constant as the ratio of the two units.

The prediction by Maxwell that light was an electromagnetic disturbance in the medium surrounding an oscillating charge and the consequent identity of the velocity of light in the ether alone with the ratio of the electrical units in the two systems of measurements used when a charge is respectively in motion or at rest and the further relation of the light constant to the dielectric constant for ponderable media, have been since fully confirmed by exhaustive experiments. His interpretation of the physical significance of the ratio of the electromagnetic unit to the electrostatic unit as a velocity of the same magnitude as that for light received remarkable confirmation in the independently conceived experiment of Rowland already referred to.

The celebrated experiments of Hertz on electric oscillations and the identification of the velocity of their propagation in the ether with that of light waves constitute a more remarkable instance of the confirmation of a brilliant conception than that of the law of gravitation itself.

If we accept these facts as confirming the supposition that light is an electric phenomenon, then we may consider the results found as data obtained by different methods for the solution of the problem, the velocity of light. It would be necessary then to examine the principles of the methods involved to determine what phase of the problem each corresponds to, *i. e.*, whether to a group-velocity or to a wave-velocity.

Consider first v, the ratio of the two units. In the derivation of the equations for the propagation of undulations in a non-conducting medium the time rate of change in the polarization, either electric or magnetic, is obtained in terms of the line integral of the force, magnetic or electric, respectively, around the bounding curve through which this polarization or flux takes place. Since now each term in the resulting equations may be expressed in either the electrostatic or electromagnetic units, the integral of these differential equations would show some connection between the constants in the problem and the ratio of the units, if different units are used, otherwise not. The well-known solution of these so-called wave-equations is a wave-potential involving as one of its factors a function periodic in time and in space. If we follow any value of the function, *i. e.*, the same phase of the disturbance, the distance we shall have gone in a unit of time is found to be the number of electrostatic units in the electromagnetic unit multiplied into the reciprocal of the square root of the constants of electric and magnetic polarization, respectively. In vacuo these constants are unity. We therefore conclude that the value of v is the wave-velocity of light and not the group velocity.

In the experiment for measuring the velocity of propagation of electric oscillations or Hertzian waves, the frequency of these oscillations is determined either directly, by observing the successive discharges in a rotating mirror, or by calculation from the capacity and induction of the electrical system. By determining the wave-length of the disturbance—usually by noting the nodes of standing waves along a wire—the velocity is found. The velocity may also be measured by noting the time for the transmission of individual disturbances over a

given interval of space. These methods all have to do with a phase of the disturbance and not with the mean of a group of oscillations, and hence correspond to the wave-velocity.

The electrical methods then all give the wave-velocity, while the optical methods thus far used do not give directly the wave-velocity or the velocity of the individual disturbances, but a velocity dependent on that of the group.

While the agreement between these electrical constants and the light constant has perhaps been the strongest factor in the identification of electromagnetic and optical phenomena, additional discoveries now give incontrovertible evidence of the common agency of the two classes of phenomena, so that these constants may now be considered with good reason to be, not so valuable as evidence of like phenomena, as independent data in determining the true value of the velocity of propagation of the medium for electrical and optical disturbances. It is true that exact quantitative evidence is lacking. The experiment of Rowland is essentially qualitative, and although his results agree approximately with values calculated from theory, more exact results are extremely desirable, although such a possibility seems to transcend present mechanical attainments. The futile attempts to definitely establish by direct experiments the electrodynamic relations between electric charges and the electromagnetic field do not disturb our confidence in the truth of the theory.

Experiment still fails to give us a mechanical reaction on a charged particle moving in a magnetic field. It fails also in giving a positive reaction on a charged particle when the magnetic field is varied. The experiments to detect the electromotive intensity produced by the variation of the velocity of a moving charge have not yet been successful. These are all essential features of the electromagnetic theory and undoubtedly will receive a successful solution in the future. On the other hand the action of a magnetic field in affecting the discharge in a vacuum electrode tube and the celebrated discovery by Hall designated as the Hall "effect" are evidence of the reality of the mechanical action on a charge moving in a magnetic field. The phenomena of discharge, in electrodeless

tubes in the presence of electric oscillations is significant of the mechanical action on a charged particle in a varying magnetic field. The discoveries by Faraday and by Zeemann—as we now interpret the association of electric charges on matter as evidenced by what we know from electrolysis—are a further confirmation of the mechanical reaction of a field of force upon moving charges. The experiments of Lecher on the magnetic action of displacement currents in a dielectric also confirm our ideas in regard to the essential characteristic of an insulating medium and the electric charges on the ultimate elements of matter. Hence we are with full reason bound to identify these constants, and may therefore examine their derivation by a closer analysis of their real significance. If on the optical side of the problem of the velocity of propagation of individual disturbances has never been attacked directly there seems to be full reason for doing so in order to complete the evidence from the standpoint of light phenomenon which we already have at hand on the electrical side.

It would be desirable to determine the velocity of a group of periodic electric disturbances under varying conditions in order to compare it with the velocity of a single disturbance.

In the methods of Fizeau and of Foucault, which are the only ones used thus far, the time of the "go" and return of a flash of light is measured. The relation of this time to that of the time of the "go" and return of a single one of the component waves is not a relation at once simple and evident. No experiments have been directly carried out to determine this relation in optical media. We have theoretical considerations of analogous examples to go by, but no direct experimental data. Lord Rayleigh has considered the problem. It has been noticed that in the progress of a group of waves in water, the individual waves appear to advance through the group and die away at the anterior limit. Stokes has explained this by regarding the group as formed by the superposition of two infinite trains of waves of equal amplitudes and of nearly equal wave-lengths advancing in the same direction. The mathematical formulation of this phenomenon as thus explained gives a resultant

periodic motion with a periodic amplitude varying from zero to the sum of the two elements. The velocity of this maximum, which is called the group-velocity U is related to the wave-velocity V by the variation with respect to the wave-length λ. If the wave-velocity V is definitely known as a function of the wave-length, then the group-velocity can be ascertained. On the other hand, we cannot determine the wave-velocity V from a complete knowledege of the function U. It is necessary that we know the relation of V to the wave-length. Rayleigh finds that $U = (1 - n)V$ if the wave-velocity V varies as the nth power of the wave-length λ. Thus for deep water waves $n = 1/2, U = 3/2 V$. In the case of aerial waves U and V are nearly the same. In this instance the ear detects the periodic variation of the resultant amplitude as beats which are propagated out with the velocity of the component waves. The resultant of two such systems of light waves may be illustrated by the interference of the two sodium lines in Newton's rings and the periodic variation in the luminosity of the rings when a great number are examined together. This of course is the fluctuation which occurs in the resultant radiations propagated into space but not capable of being seen by the eye.

The argument from the kinematical point of view for the relation of the two velocities is not entirely beyond criticism as this requires a gradual variation in the amplitude according to the cosine law. As the group sent out by either of these two methods must deviate considerably from this law, it would be necessary to include a number of harmonics in Fourier's series to give the proper configuration to the group. In order that we may then use the kinematical argument we must assume these harmonics are rapidly frittered down and that they never return. This may have some significance in the toothed-wheel method, where some observers have noted a coloration of the return image. Further analysis of the kinematical problem is necessary before we can feel sure of its application to the physical counterpart. The argument which Lord Rayleigh has advanced, based on the consideration of the energy propagated, assumes absorption due to a frictional term proportional to the velocity. Now while absorption in ponderable

media is explained on the assumption of imbedded particles in the ether of some specific period, it has not yet been proven that this is the only way in which absorption may take place. If there be absorption in the ether itself it is not easy to see just how it does occur. On the assumption already made above it would be impossible for the ether to transmit waves of certain frequencies corresponding to its natural period and we should have selective absorption, a condition quite contrary to the conception of such a medium. On the above assumption, however, the ratio of the energy passing a given point in a unit of time to the energy in the train after this unit of time is the ratio of the group-velocity to the wave-velocity. Thus we see the ratio depends directly on the amount of absorption. It is not quite clear, however, that this relation would hold for absorption by some other mode. We may then feel some hesitancy in accepting this relation of the group-velocity to the wave-velocity as based on either the kinematical analogy or the energy argument. We must therefore fall back for the solution upon direct experimental means. The significance of such an experimental solution to the problem of the propagation of undulations should not be underestimated. Investigations of these two velocities for monochromatic light, such as from cadmium or mercury, in highly dispersing substances like carbon disulphide or alphamonobromonapthaline or dense glass of Faraday, now seem entirely possible and sufficient for the solution of the problem.

In the case of the ether the arguments which can be advanced in regard to velocity of light for different colors indicate the same velocity for all colors. It was pointed out by Arago that any difference in velocity should produce a coloration in any luminous body in the universe which should vary rapidly in intensity. Thus in the observations on the eclipse of Jupiter's satellites they should momentarily show at the instants of disappearing and reappearing a coloration complementary in the two cases. Nothing of this kind has been recorded. Again in the case of Algol, Newcomb estimated, from its probable distance—greater than 2,000,000 radii of the earth's orbit and the time for light to reach us, 30 years—that a difference in

time between the blue and the red rays of one hour would give a difference in velocity of four parts in a million. In the remarkable changes in Nova Persei last year, its complete spectrum appeared to be visible even though the changes in its intensity were far more rapid than in the case just mentioned. As no trace of coloration has ever been observed this difference of time cannot exceed a fraction of an hour. It should be mentioned, however, that in the experiments of Young and Forbes, the velocity of blue light was apparently about 1.8 per cent. greater than that of red light. Both Michelson and Newcomb claim that this would have been very distinctly observed in their experiments with the rotating mirror in the spreading out of the image of the slit into a distinct spectrum. A further instance is cited by Lord Rayleigh which may be of value. If we examine the position of the bands in the spectrum of glowing gases, we find certain harmonic relations. Now if these rays had different velocities in the free ether the position of the bands would be effected and the harmonic relations, apparently holding as deduced from the spectra observed, would not give the harmonic relations in the radiants themselves; or, *vice versa*, such harmonic relations between the radiants would not give harmonic distribution of the bands in the spectrum. From another standpoint it may be mentioned that on any theory of an optical medium we know that either a difference in velocity or a dispersion requires incomplete transmission. This may be due to internal reflection or to transformation into heat. The transmission would also be differential. Thus only a part of the light of the distant stars would reach the eye and this would be more and more colored as the distance increased, due to the differential transmission. No effect of this kind can be observed even in the nebulæ which are so remote that the telescope cannot resolve them, although the spectroscope gives us unquestioned evidence of their stellar nature.

These arguments from the astronomical point of view are, however, uncertain and indirect. Until we can determine to a close approximation the wave-velocities of different colored rays in ponderable media as well as in the ether, we cannot be

assured that we are entitled to consider the determination by the group methods used heretofore as sufficient to give us the absolute velocity of light. Even if we regard the evidence from astronomical observations of the common velocity in space for all colors, and from this conclude that the absolute velocity is the group-velocity, as the equations of Lord Rayleigh show with the assumptions he makes, we are still lacking sufficient data for the relation in the case of ponderable media.

In the discussion of the results by the toothed-wheel method and the rotating-mirror method, considerable difference of opinion has been expressed as to just what we obtain by the latter method. There seems to be no dissenting opinion that the toothed-wheel method gives the group-velocity directly, for here we have the time of transit of an interrupted beam of light. In the rotating-mirror method the ray is also intermittent. Lord Rayleigh seems first to have raised the interesting question as to what is actually measured in these experiments, and in his first note states that the rotating-mirror method gives the group-velocity U. In a later article he arrives at a different result and gives the square of the wave-velocity divided by the group-velocity, V^2/U. Evidently unless we know the relation of the two we can find neither if this be correct. Now this relation is not certainly known as pointed out above. On the other hand Gouy, however, dissents from this second view and shows that the group-velocity U is the quantity determined by the rotating-mirror method. Schuster in a later article dissents from Gouy's conclusion and corrects Lord Rayleigh's second result, and gives the square of the wave-velocity divided by twice the wave-velocity minus the group-velocity, $V^2/(2V-U)$. J. Willard Gibbs in a later article points out an error in the derivation of this relation by Schuster and shows that the group-velocity is after all what is determined by the rotating-mirror method. He shows further that the results of Michelson's observation on carbon disulphide give a closer agreement with the refractive index with this conclusion arrived at by Schuster. Lord Rayleigh suggests in his second note that by placing a lens in the path of the ray so that the fixed mirror

is at its focus the rotation of the wave-front caused by the rotating mirror would be corrected on the return and we should thus find the absolute velocity V. This is evidently in error, as Schuster showed, as the rotations would be added. Even if neutralized we should not obtain V, but U. In a reply to a communication by the writer to Lord Rayleigh in 1890 as to such a method for the absolute velocity he has indicated a misapprehension on this matter and expressed his opinion as to the probable correctness of Professor Gibb's conclusion which agrees with his first position. With the exception of Schuster the rotating mirror method seems to be accepted by all as giving the group-velocity. The correction for the rotation between two successive wave planes which is erroneously given by Schuster would give the group-velocity and thus an agreement with the results of the rest. While the observations of Michelson on carbon disulphide give the closest agreement with this result, more exact data for specific wave-lengths are desirable in order to confirm the theoretical conclusion.

In studying the question of group- and wave-velocities in connection with dispersion the following two methods occurred to the writer: The first one was for increasing the sensibility of the old methods, and the second one for observing the wave-velocity directly by means of interference. In 1889 he was invited by President Hall to Clark University to conduct, among other things, an investigation on some special problem. The dispersion in air was selected, and a combination of the arrangements of both Fizeau and Foucault which had occurred to the writer before was adopted. The essential condition in Fizeau's method is to produce an intermittence in a beam of light. This is done mechanically by the rotation of a toothed wheel.* It is quite clear that if the wheel were fixed and the ray rotated the condition of intermittence would be fulfilled. It would then be merely a matter of arranging a suitable optical system to maintain a fixed direction for the ray while

*In the March number of the *Philosophical Magazine* for this year, Professor Michelson describes a similar arrangement which occurred to him independently during his experiments on the motion of the ether.

in transit between the two stations. Any such optical system would avoid the inerta inherent in a mechancial system and would thus allow of much greater speed and consequent sensibility. Through the courtesy of the Secretary of the Navy and the active assistance of Professor Newcomb, the phototachometer of the latter was secured to carry out this experiment at the University of Nebraska instead. This instrument seemed to be well suited for a preliminary experiment on

Fig 1

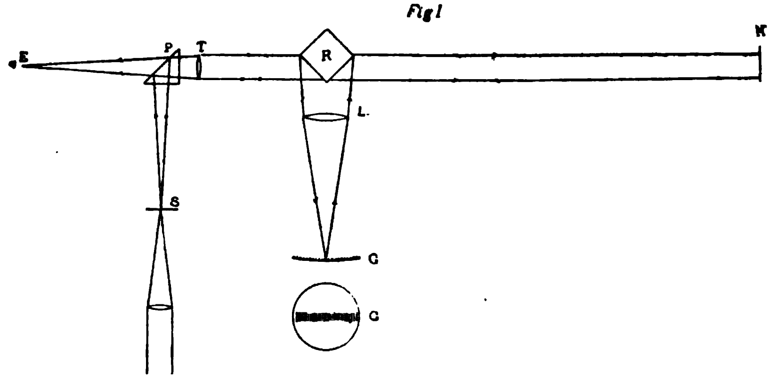
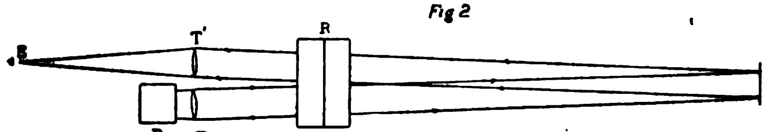


Fig 2



account of the rectangular shape of the rotating mirror and the number of reflecting faces available. Figures 1 and 2 show the arrangement used and the path of the ray. The original apparatus was changed slightly, the two telescopes T and T' being shifted so that their axes passed through the middle of one set of faces when these stood at 45° to the same. The other additions were the lenses L the grating G and the plane mirror M. The instrument was originally mounted so as to use the concave mirror belonging to the instrument itself, which had a radius of curvature of 3,000 meters. Owing to improvements about the campus it became necessary to re-

move the piers and discontinue the experiment for several years. It was again finally mounted in the basement of the Physical Laboratory on a much smaller scale, and the flat mirror M used at a distance of about fifteen meters from the rotating mirror R. The lens L was a telescope lens of one meter focus and ten centimeters aperture. The concave mirror G had a radius of curvature of one meter and an aperture of ten centimeters. A narrow strip across this mirror was divided into equal bright and dark spaces of ten to the millimeter. This was accomplished by means of a diamond making five deep strokes in each alternate space. In this way normally incident light would be returned over the same path from the bright spaces, but be scattered from the cuttings in the adjacent spaces, so that very little of it would be returned in the direction of incidence. A lens converged the sun's rays on the slit S from which a beam passed to the mirror P through the collimator lens T to the upper part of the adjoining face of the rotating mirror R from which it was reflected at 45° through one-quarter of the lens L and brought to a focus on the grating mirror G. From this it was reflected through the lower opposite quarter of the lens to the lower part of the next face of R and thence reflected at 45° to the plane mirror M as parallel light. This reflected it to the upper part of the same face of R thence through L to G and back to the lower half of the face of R upon which it was first incident and thence through the observing telescope T' below the collimator, to the eye. It is clear from the diagram and from the principle that an even number of reflections of a ray system from a moving reflection system does not alter their direction that the incident and the reflected rays from the rotating mirror R will remain parallel to each other and hence will always meet the mirror M at the same point during the rotation of R. For the moment let us assume the image of the slit S just covers one of the bright spaces. By proper adjustment of M the return image can be made to coincide with it. Usually it was displaced slightly below it so as to observe the relative positions of the two when the mirror R was rotated so as to carry the images across the grating. If now, during the time of transit from G and back,

the mirror has rotated through an odd number of spaces no appreciable light will be reflected from G through T' to the eye. If the rotation correspond to an even number of spaces, the eye would see an enfeebled image of the slit S. If the mirror were varying in speed the eye would see this image pass successively through maxima and minima, depending on the rate of change of the rotating mirror R. Suppose now the image of S covers any number of spaces on G the eye will see an image of S, but crossed by bright and dark spaces corresponding to those on G. With the corresponding variations in the speed of the rotating mirror the eye will see corresponding fluctuations in this image. In this way the eye may be able to determine the minima by comparison with the darker spaces which remain of constant intensity.

The aperture of the "sending" telescope was 4.5 cm. but the effective aperture with the rotating mirror at 45° was only 2.5 cm. The actual spacing was .02 cm. between the bright lines, which is well within the limits of good definition. The mirror could be driven up to 250 revolutions or more per second without serious vibration. Thus the ray could be interrupted about 10,000,000 times in a second. This would give a group of waves about fifteen meters long. If the limits of resolving power and speed were used 40,000,000 interruptions could be obtained and the lengths of the groups could be reduced to less than four meters. Thus there would be about 6,000,000 waves in each group. As the eye can observe a change in intensity of less than one per cent., the method would thus be capable of detecting the existence of a velocity if the total distance of the mirror M were less than 2 cm. from the grating. This shows the sensibility which the combination of the methods of Fizeau and Foucault may give under very favorable conditions.

If the velocity were different for different colors this method would be capable of showing even a very slight difference. For example the difference in velocity between the extreme red and the violet rays in carbon disulphide is about one-sixteenth. For air this difference is about one part in one hundred thousand. Now an addition of 5 per cent. of one of these

colors and a subtraction of the same amount of the other from white light will produce a perceptible change in time. Thus if we consider a five per cent. change instead of one per cent. as mentioned previously, and multiply this by sixteen we obtain 1.6 meters as the length of a column of carbon disulphide between the grating and the fixed mirror, in which we could just detect the dispersion of light. Similarly in the case of air we have to multiply by five and by 100,000 and obtain about ten kilometers to produce the necessary dispersion in air. It is very doubtful whether this sensibility can be actually realized. In the preliminary experiments with his instrument sunlight was used. The scattered light from different parts of the system prevented the contrast between the light and dark spaces in the return image which would be necessary for such a high sensibility. By adjusting the mirror M so that the images of the bright spaces of the grating should fall on the dark spaces on their return, the appearance for an eclipse could be studied. In reference to the intensity of the return image, if we allow fifty per cent. less from successive reflections and remember that the angle of the grating was only one sixtieth of the circumference, we find only about one per cent. of the light available in the return image. Thus with the mechanical system of Fizeau's toothed wheel we should have one hundred times the light available for the same aperture. The preliminary experiments were made under favorable conditions, but indicated a greater sensibility than that heretofore obtained. With sunlight sufficient intensity would be available for the experiments just referred to. With the apparatus as mounted too much instability was experienced to obtain satisfactory definition with the rotating mirror and the motor and blower which drove it in motion. The condition of the faces of the rotating mirror also prevented distinct definition. In order to use all four faces they required refiguring and the angles between them recut. The lack of funds to make these changes and the recall of the instrument have caused the experiments to be interrupted several times and finally abandoned until the means for building apparatus more suitable for the purpose and for carrying out the experiment can be

obtained. This method will give the group-velocity U directly according to the criticism already referred to on the method of the rotating mirror. The possibility of obtaining important data on group-velocity in different media by so sensitive a method, and also the determination of the velocity of light in a vacuum itself warrants further efforts being made along this line. These experiments were initiated in 1889 and discontinued a half dozen years later in the way mentioned.

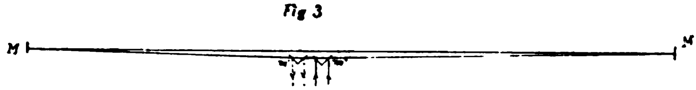
It is doubtful whether there are other methods for determining the group-velocity of greater sensibility. One method of considerable promise is by means of polarized light. Two rays of light pass through a Nichol and a half-wave plate. Each is reflected from each of two mirrors respectively. By properly focusing we should have a half-shade combination which on rotating the half-wave plate and the Nichol about the common axis would give a difference in the intensity of each return ray. Half-shade systems have a sensiblity as high as one thousandth of a degree in the limit. Such a Nichol could probably be rotated at a speed exceeding two thousand per second. Polishing machines are now run above one hundred thousand a minute. Foucault's mirror rotated eight hundred times a second. At such a speed and sensibility a velocity in light could be detected over a distance of about twenty centimeters.

Another system depending upon electric oscillation would require much the same optical system. A prism of glass between two electrodes as arranged for the Kerr "effect" in a dielectric is placed beyond a half-wave plate and a Nichol prism which is fixed. If now the glass is subjected to electric strain by rapid oscillations, the fields from each mirror are lighted up differently and the limiting distance at which this difference is observable will be the same as stated previously. Probably oscillations several hundred millions a second would be possible with such a condenser system. Forty millions a second was the limit with the rotating mirror and grating as described above. This could probably be increased to one hundred millions a second with a suitable rotating mirror. Instead of using the Kerr "effect" a piece of Faraday glass within a single

turn of foil could be used for very high frequencies and the Faraday "effect" employed instead. Probably the same order of sensibility could be obtained as with the former. It is hoped to make preliminary experiments on these promising methods which would probably give shorter groups or types of waves than any of the others. Here we should not have an intermittence but a property impressed at intervals upon a continuous train of waves, and the relation of the velocity of that property to the wave-velocity would have to be determined.

No method for determining the wave-velocity of light seems yet to have been proposed. The following arrangement occurred to the writer in 1890 while experimenting with the phototachometer as already described. Suppose that in two interfering systems of rays we could alter the length of the path of one or both of the rays during their transit from their common source to their final point of meeting, there would be a displacement of the bands depending on the relative retardation introduced into the paths during this interval. Figure 3

Fig 3



illustrates the first conception of the system. A beam of parallel light, from a lens, say, strikes the two adjacent faces of a rectangular mirror, each face of which reflects the rays in opposite directions to the mirrors M and M', each of which reflects the corresponding rays to the other and thence both return to the mirror, thus traversing each other's paths. If now the mirror m is displaced to the position of m' in this interval the path of one ray will exceed that of the other by twice the distance through which the mirror has moved. Knowing this distance, by means of the wave-length and the time it takes to displace the mirror a given distance, we have at once the time of displacement of the mirror from the position m to m' and thus the time of transit of any one ray around this path, and hence the wave-velocity. Considerable difficulty was experienced in devising a method of displacement of sufficiently

high speed. If the mirror *m* is mounted on a rotating disc the rays would be reflected beyond the mirrors *M* and *M′* and the interference would be changed by the angular motion of the mirror. The mechanical oscillator of Mr. Tesla suggested itself as capable of giving possibly sufficient speed. The variation in the speed which would cause the bands to be superimposed and thus obliterated rendered this method impossible. The same difficulty would be experienced with any reciprocating means. The compensation for angular movement of a disc did not seem clear and its use was abandoned for a time. Instead of this the system indicated in Figures 4

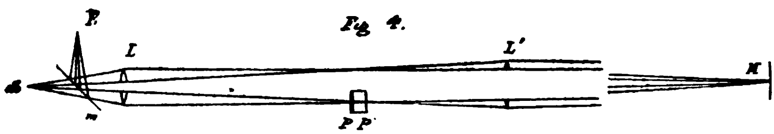


Fig. 4.

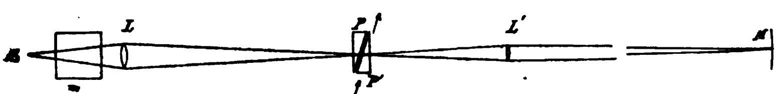


Fig. 5.

and 5 was tried. *L* and *L′* are two bisected lenses, *P* and *P′* two prisms, one of which, *P′*, is mounted on a rotating disc so that the total thickness would be increased or diminished by its rotation. The split lens *L* forms two images of the beam from the slit *S* and one-half of its aperture. In one focus the double prism is placed. The split lens *L′* forms coincident images on the distant mirror *M*, which reflects each ray back over the path through the opposite halves of the lenses to the mirror *m*, which reflects the light to the eye. If now the prism *P′* be moved in the interval of transit of this optical circuit the ray returning through it will be retarded over the other. Knowing the constants of the prism and the speed of the disc we can calculate, in this way, the wave-velocity. The interference bands in this system remained indistinct during the movement of the prism over an arc of five to ten degrees. The length of this system in the preliminary experiment was about

thirty meters. With sunlight and a much greater distance, distinct bands could easily be obtained with only one-fiftieth the intensity, which represents the fraction of the incident light available during one revolution. Here again we are met with the difficulty of obtaining an insufficient component velocity in the direction of the ray, which is the velocity of the disc into the cosine of the angle of the prism into the index of refraction less one.

Through a fortunate idea the rotating disc was made possi-

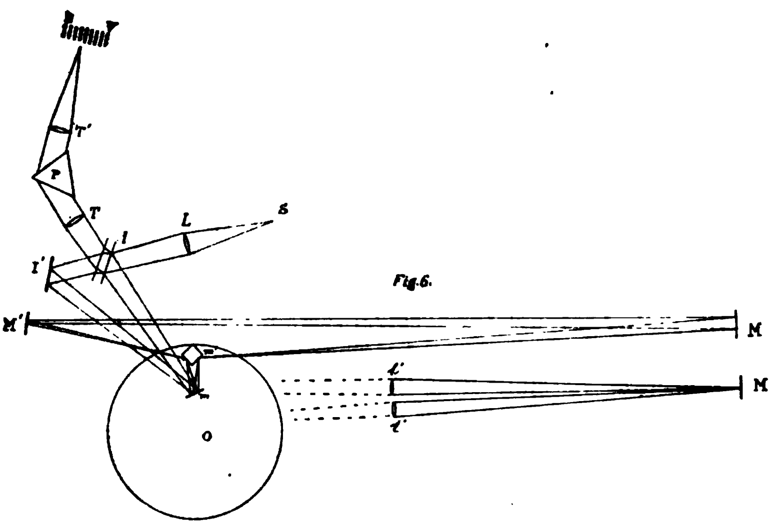


Fig. 6.

ble, and the final and most serious difficulty was overcome. Figure 6 gives the arrangement with somewhat distorted details to show the optical relations. The principle that an even number of reflections in a rotating system does not change the relation of the incident to the transmitted ray was made use of. A further difficulty had to be met in maintaining the ray upon the reflecting elements, as the rotation of the reflected ray is twice that of the reflector. If the radius of rotation is reduced one-half the linear movement of any point is reduced one-half. These considerations applied to two mirrors on the rotating disc met the required conditions. Thus the mirror m is placed just half the distance of the mirror m' from the center.

A ray incident upon m is reflected to m' and thence reflected in some definite direction. If the disc now rotate, the ray will rotate through twice the angle, but still strike the mirror m' in the same point if these conditions are fulfilled and will be reflected off parallel to its former direction. This relation will be maintained as long as the above conditions hold, which will be, approximately, through a considerable fraction of the circumference. This will be best satisfied when the mirror m is normal to the radius, the incident ray being thus nearly normal. The arrangement as finally adopted is shown in the figure. Light from the slit S is converged by a lens L to a half silvered plate I, one beam being reflected and the other passing through and being reflected by the mirror I'. Both converging beams strike the mirror m at the same point and are then reflected, the first beam to the adjacent face of the rectangular mirror m' and the second to the opposite face, where they form images of the slit S. The first beam is reflected to M' then to M and finally to a focus on m'. Thence the two rays trace each other's paths and are reflected and transmitted respectively by the plate I through the spectral system P to the eye, where interference bands are formed. Thus, aside from other losses by reflection one-fourth of the light reaches the eye. The distant mirror M may be concave and of the proper focus for the system; or two lenses I and I' may be used so as to obtain a greater aperture to the beam. These two rays will in general travel over slightly different paths and hence give bands which may be conveniently analyzed by means of channeled spectra. If now the disc rotates the path of one of the rays will become greater than the other and the interference bands will shift. If a spectrum is used the bands will move across the field, increasing or decreasing in number. If the adjustment is initially made so that the paths are the same, no bands will appear until the disc is set in motion. By counting the number passing any point we can obtain the order of the interference for that wave-length, and from the dimensions and speed of the disc determine the wave-velocity for that color. From the position of the other bands at this instant, we can calculate the velocity of that color. Thus we have the

means at hand for obtaining the wave-velocity for all colors, from which the group-velocity for the same can at once be obtained. The radius to the disc m' is 15 cm. and a speed of 500 per second is assured. The concave mirror M has an aperture of 15 cm. and a radius of curvature of 15 M. This is the arrangement now being used. With this velocity, assuming a band can be read to one-thirtieth part, a distance of only .3 cm. would show a velocity. The rays during transit may be made to pass within a tube which can be evacuated, connecting M and M'. Another arrangement may be used when M is placed at a much greater distance and is shown in the annexed diagram. l and l' are two lenses whose foci are M and their conjugate foci on each face of M' respectively.

It seems certain now that the wave-velocity in different media, as well as in vacuo, may be determined to a high degree of accuracy and that too for any color.

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On the Effect of Electrolytic Condensers in Alternating Current Circuits. By A. Trowbridge and E. R. Wolcott, University of Wisconsin, Madison, Wis.

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ABSORPTION OF SALTS IN AQUEOUS SOLUTIONS BY POWDERED QUARTZ. BY LYMAN J. BRIGGS, U. S. Dept. Agriculture, Washington, D. C.

ON THE OSMOTIC PRESSURE OF ABSORBED SALTS. BY LYMAN J. BRIGGS, U. S. Dept. Agriculture, Washington, D. C.

ON THE RAPID FILTRATION OF TURBID SOLUTIONS AND THE CHANGE IN CONCENTRATION PRODUCED BY THE POROUS SEPTUM. BY LYMAN J. BRIGGS, U. S. Dept. Agriculture, Washington, D. C.

[Published in Bull. 19, Bureau of Soils, U. S. Dept. Agriculture.]

ON THE FORMATION OF DEW BOWS. BY LYMAN J. BRIGGS, U. S. Dept. Agriculture, Washington, D. C.

NOTE ON A NEW FORM OF LABORATORY SWITCH-BOARD JACK. BY F. C. CALDWELL, University of Ohio, Columbus, Ohio.

NOTE ON A NEW VARIABLE IRONLESS INDUCTION COIL FOR LARGE CURRENTS. BY F. C. CALDWELL, University of Ohio, Columbus, Ohio.

MOLECULAR FRICTION IN STEEL AND PHOSPHOR-BRONZE. BY J. O. REED, University of Michigan, Ann Arbor, Mich.

YOUNG'S MODULUS FOR PHOSPHOR-BRONZE, BETWEEN 20° AND 300° C. BY J. O. REED, University of Michigan, Ann Arbor, Mich.

PHOTOGRAPHIC STUDY OF THE ALTERNATING ARC. BY GEO. A. HOADLEY, Swarthmore College, Swarthmore, Pa.

THE NERNST LAMP. BY A. J. WURTS, Pittsburg, PA.

ABSORPTION SPECTRA OF THE PERMANGANATES. BY B. E. MOORE, University of Nebraska, Lincoln, Neb.

THE INDEX OF REFRACTION AND THE ABSORPTION OF FUCHSINE. BY W. B. CARTMEL, University of Nebraska, Lincoln, Neb.

DETERMINATION OF DISPERSION BY MEANS OF CHANNELED SPECTRA. BY S. R. WILLIAMS, University of Nebraska, Lincoln, Neb.

The following papers were read before a joint session of Section B and the American Physical Society:

RESULTS OF RECENT MAGNETIC INVESTIGATIONS. BY L. A. BAUER, U. S. Coast and Geodetic Survey, Washington, D. C.

[Published in Journal of Terrestrial Magnetism and Atmospheric Electricity.]

SOME RECENT INTERESTING MAGNETIC DISTURBANCES REGISTERED AT THE COAST AND GEODETIC SURVEY MAGNETIC OBSERVATORIES. BY L. A. BAUER, U. S. Coast and Geodetic Survey, Washington, D. C.

[Published in Journal of Terrestrial Magnetism and Atmospheric Electricity.]

EXPERIMENTS ON THE ELECTROLYSIS OF RADIO-ACTIVE SOLUTIONS. BY GEO. G. PEGRAM, Columbia University, New York, N. Y.

ON THE RELATION BETWEEN THERMO-ELECTRIC POWER AND CHANGE OF LENGTH, CAUSED BY MAGNETIZATION. BY EDWARD RHOADS, Haverford College, Haverford, Pa.

Published in Physical Review.]

Absorption Spectrum of Carbon. By E. L. Nichols and E. Blaker, Cornell University, Ithaca, N. Y.

[Published in Physical Review.]

Persistence of Vision in Color-blind Subjects. By Frank Allen, Cornell University, Ithaca, N. Y.

Heat of Vaporization of Liquid Air. By J. S. Shearer, Cornell University, Ithaca, N. Y.

[Published in Physical Review.]

The Magnetic Field Produced by a Flight of Charged Particles. By R. W. Wood and Harold Pender, Johns Hopkins University, Baltimore, Md.

Note on the Thermal Unit. By H. T. Barnes, McGill University, Montreal, Canada.

On the Action of a Condenser in an Induction Coil. By J. E. Ives, University of Cincinnati, Cincinnati, Ohio.

Note on a Graphical Method for Tracing Rays Through Optical Prisms. By William Fox, College of the City of New York, New York, N. Y.

On a New Half-shade Polariscope. By D. B. Brace, University of Nebraska, Lincoln, Neb.

AN EXPLANATION OF THE FARADAY AND ZEEMAN EFFECTS. BY D. B. BRACE, University of Nebraska, Lincoln, Neb.

ADDITIONAL NOTES ON THE CONSTRUCTION AND USE OF THE BRACE SPECTROPHOTOMETER. BY S. B. TUCKERMAN, University of Nebraska, Lincoln, Neb.

SECTION C.

CHEMISTRY.

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PAPERS READ.

[The following papers were read before joint sessions of Section C and the American Chemical Society.]

BESSEMER AND OPEN-HEARTH STEEL PRACTICE. BY EDWARD H. MARTIN AND WM. BOSTWICK.

MANUFACTURE OF OPTICAL GLASS. BY GEO. A. MACBETH, Pittsburg, Pa.

THE OZONE FROM POTASSIUM CHLORATE. BY EDWARD HART, Lafayette College, Easton, Pa.

ARSENIC PENTACHLORIDE. BY CHARLES BASKERVILLE AND H. H. BENNETT, University of North Carolina, Chapel Hill, N. C.

[Published in Journal of American Chemical Society.]

PREPARATION OF PURE PRÆSEODYMIUM COMPOUNDS. BY CHARLES BASKERVILLE AND J. W. TURRENTINE, University of North Carolina, Chapel Hill, N. C.

[Published in Journal of American Chemical Society.]

THE DEPORTMENT OF PURE THORIUM AND ALLIED ELEMENTS WITH ORGANIC BASES. BY CHARLES BASKERVILLE AND F. H. LEMLY, University of North Carolina, Chapel Hill, N. C.

[Published in Journal of American Chemical Society.]

THE CHLORIDES OF RUTHENIUM. BY JAS. LEWIS HOWE, Washington and Lee University, Lexington, Va.

[Published in Journal of American Chemical Society.]

MALLEABLE IRON. BY H. E. DILLER.

THE OLD AND THE NEW IN STEEL MANUFACTURE. BY WM. METCALF, Pittsburg, Pa.

VALENCE. BY IRA REMSEN, Johns Hopkins University, Baltimore, Md.

AN EXPLANATION OF QUANTIVALENCE AND OF STEROCHEMISTRY. BY T. W. RICHARDS, Harvard University, Cambridge, Mass.

THE EXACTNESS OF FARADAY'S LAW. BY T. W. RICHARDS, Harvard University, Cambridge, Mass.

THE ELECTRICAL CONDUCTIVITY AND FREEZING POINTS OF AQUEOUS SOLUTIONS OF CERTAIN METALLIC SALTS OF TARTARIC, MALIC AND SUCCINIC ACIDS. BY O. F. TOWER, Adelbert College, Cleveland, Ohio.

[Published in Journal of American Chemical Society.]

IONIC VELOCITIES IN LIQUID AMMONIA SOLUTIONS. B E. C. FRANKLIN, Kansas State University, Lawrence, Kans.

A THERMOCHEMICAL CONSTANT. BY F. W. CLARKE, U. S. Geological Survey, Washington, D. C.

[Published in Journal of American Chemical Society.]

Solubility, Electrolytic Conductivity, and Chemical Action in Liquid Hydrocyanic Acid. By Louis Kahlenberg and Herman Schlundt, Madison, Wis.

[Published in Journal of Physics and Chemistry.]

Molecular Attraction. By J. E. Mills.

On Conductivity. By Geo. A. Hulett.

Relation between Negative Pressure and Osmetic Pressure. By George A. Hulett.

A New Apparatus for Measuring the Co-efficient of Expansion of Gases. By T. W. Richards and E. L. Mark, Harvard University, Cambridge, Mass.

The Expansion of a Gas into a Vacuum and the Kinetic Theory of Gases. By Peter Fireman, Washington, D. C.

Electrolytic Deoxidation of Potassium Chlorate. By Wilder D. Bancroft, Cornell University, Ithaca, N. Y.

[Published in Journal of Physics and Chemistry.]

The Solid Phases in Certain Alloys. By Wilder D. Bancroft, Cornell University, Ithaca, N. Y.

[Published in Journal of Physics and Chemistry.]

Otto Hoffman By-Product Coke Ovens. By C. G. Atwater.

CRUCIBLE STEEL MANUFACTURE. BY E. L. FRENCH.

A PROPOSED DISTILLATION TEST FOR FIREPROOFED WOOD BY C. F. MCKENNA.

GLUTEN FEED ANALYSIS. BY EDWARD GUDEMAN.

A NEW CONSTANT HIGH TEMPERATURE BATH. BY CHARLES BASKERVILLE, University of North Carolina, Chapel Hill, N. C.

[Published in Journal of American Chemical Society.]

COMPARISON OF RESULTS OBTAINED BY DIFFERENT METHODS OF DETERMINING THE AMOUNT OF OXYGEN ABSORBED BY WATERS CONTAINING OXIDIZABLE SUBSTANCES. BY LEONARD P. KINNICUTT, Worcester Polytechnic Institute, Worcester, Mass.

AN IMPROVED GRINDER FOR ANALYSES OF MOTHERBEETS. BY DAVID L. DAVOLL, JR.

[Published in Journal of American Chemical Society.]

QUANTITATIVE BLOWPIPE ANALYSES OF BEAD COLORATIONS. BY JOSEPH W. RICHARDS.

DETERMINATION OF GLUCOSE. BY EDWARD GUDEMAN.

THE RETENTION OF ARSENIC BY IRON IN THE MARSH TEST. BY C. L. PARSONS AND M. A. STEWART, Durham, N. H.

[Published in Journal of American Chemical Society.]

THE IDENTIFICATION AND ANALYSIS OF MALT LIQUORS. BY C. L. PARSONS, Durham, N. H.

A NEW ELECTRIC TEST RETORT. BY CHAS. F. MCKENNA.

THE SOLUTION OF STEEL IN FERRIC AND POTASSIUM CHLORIDES FOR THE ESTIMATION OF CARBON. BY GEO. W. SARGENT.

[Published in Journal of American Chemical Society.]

THE DISTRIBUTION OF HYDROGEN SULPHIDE TO LABORATORY CLASSES. BY C. L. PARSONS, Durham, N. H.

THE HYDROLYSIS OF MALTOSE AND DEXTRINE FOR THE DETERMINATION OF STARCH. BY W. A. NOYES, G. CRAWFORD, C. H. JUMPER, AND E. L. FLORY, Rose Polytechnic Institute, Terre Haute, Ind.

SOME NOTES ON GLASS AND GLASS MAKING. BY ROBERT LINTON.

PLATE GLASS MANUFACTURE. BY F. P. MASON.

CONDENSATION OF CHLORAL WITH THE NITRANILINES. BY A. S. WHEELER AND H. R. WELLER, University of North Carolina, Chapel Hill, N. C.

THE COMPOSITION OF URINE AND ITS RELATION TO ELECTRICAL CONDUCTIVITY. BY JOHN H. LONG, Northwestern University, Chicago, Ill.

[Published in Journal of American Chemical Society.]

Symmetrical Trimethylbenzyl, Symmetrical Trimethylbenzene Hydrazone and Some of its Derivatives. By Everhart P. Harding, University of Minnesota, Minneapolis, Minn.

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1. 4. Dimethybenzyl, 1. 4. Dimethylbenzene Hydrazone and Some Derivatives. By Everhart P. Harding, University of Minnesota, Minneapolis, Minn.

The Action of Valerianic Acid and Valeric Aldehyde Upon Antipyrin. By David C. Eccles, Agricultural College, Pullman, Wash.

A Chemical Study of the Pitch of the Northern Pine. By G. B. Frankforter, University of Minnesota, Minneapolis, Minn.

Derivatives of Eugenol. By G. B. Frankforter and Max Lando, University of Minnesota, Minneapolis, Minn.

The Reaction of Bromide Upon Oxalic Acid. By T. W. Richards and W. N. Stull, Harvard University, Cambridge, Mass.

Isomeric Oxy-Azocompounds. By W. McPherson, Ohio State University, Columbus, Ohio.

[Published in Journal of American Chemical Society.]

Reactions Between Acid and Basic Amides in Solution in Liquid Ammonia. By E. C. Franklin and O. F. Stafford, Kansas State University, Lawrence, Kans.

THE INFLUENCE OF THE GROWTH OF MOLD ON THE CHEMICAL COMPOSITION OF OLEOMARGARINE AND BUTTER. BY C. A. CRAMPTON, U. S. Treasury Department, Washington, D. C.

[Published in Journal of American Chemical Society.]

CARBYL SALTS. BY M. GOMBERG, University of Michigan, Ann Arbor, Mich.

PICRYL DERIVATIVES OF SOME PHENOLS. BY H. W. HILLYER, University of Wisconsin, Madison, Wis.

CAMPHORIC ACID: SYNTHESIS OF TRIMETHYLPARACONIC ACID. BY W. A. NOYES AND A. M. PATTERSON, Rose Polytechnic Institute, Terre Haute, Ind.

RECENT PROGRESS IN THE FIREPROOFING TREATMENT OF WOOD. BY S. P. SADDLER.

[Published in Journal of American Chemical Society.]

MANUFACTURE OF WHITE LEAD. BY G. O. SMITH.

ON SOME EXPANSION MEASUREMENTS OF PORTLAND CEMENT. BY E. D. CAMPBELL.

SOME PRELIMINARY STUDIES ON THE CONDITIONS INFLUENCING THE CLINKERING OF PORTLAND CEMENT. BY E. D. CAMPBELL.

A NEW GLASS OF LOW SOLUBILITY. BY G. E. BARTON, Millville, N. J.

[Published in Journal of American Chemical Society.]

A Process for Rendering Phosphoric Acid Available. By Charles Baskerville, University of North Carolina, Chapel Hill, N. C.

A Contribution to the Chemistry of Some of the Asphalt Rocks Found in Texas. By H. W. Harper, University of Texas, Austin, Tex.

Occurrence and Importance of Soluble Manganese Salts in Soils. By E. E. Ewell, U. S. Department Agriculture, Washington, D. C.

Black Rain in North Carolina. By Charles Baskerville, University of North Carolina, Chapel Hill, N. C.

[Published in Monthly Weather Review.]

The Discovery of a Dextrose Factor in Saturated Cane Sugar Solutions. By L. W. Wilkinson, Tulane University, New Orleans, La.

The Composition of Myrtle Wax. By W. R. Smith and F. B. Wade.

A Modification of the Calorimeter for Determining the Heat of Chemical Reactions. By Albert W. Smith, Case School of Applied Science, Cleveland, Ohio.

[Published in Journal of American Chemical Society.]

An Error in the Chronic Acid Method for Determining Carbon in Iron. By Albert W. Smith, Case School of Applied Science, Cleveland, Ohio.

[Published in Journal of American Chemical Society.]

SECTION D.

Mechanical Science and Engineering.

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ADDRESS

BY

HENRY S. JACOBY,

VICE-PRESIDENT AND CHAIRMAN OF SECTION D FOR 1901.

RECENT PROGRESS IN AMERICAN BRIDGE CONSTRUCTION.

In view of the great achievements in engineering construction which characterized the latter part of the nineteenth century in America, it seems appropriate to give a brief review of the most recent progress in one of its departments, that of bridge construction. It appears to be the more fitting since the place of this meeting of the Association is the greatest center of production of the material which constitutes the bulk of that used for modern bridges.

The application of scientific principles to the construction of bridges is more complete to-day than ever before. This statement applies to the specified requirements which the finished structure must fulfil, the design of every detail to carry the stresses due to the various loads imposed, the manufacture of the material composing the bridge, the construction of every member in it, and finally the erection of the bridge in the place where it is to do its duty as an instrument of transportation.

A close study of the economic problems of transportation in the United States and the experimental application of its results led the railroad managers to the definite conviction that, in order to increase the net earnings while the freight rates were slowly but steadily moving downward, it was necessary to change the method of loading by using larger cars drawn by heavier locomotives, so as to reduce the cost of transportation per train mile. While these studies had been in

progress for a number of years and there was a gradual increase in the weight of locomotives, it is only within the past five years that the test was made, under favorable conditions and on an adequate scale, to demonstrate the value of a decided advance in the capacity of freight cars and in the weight of locomotives for the transportation of through freight. The test was made on the Pittsburg, Bessemer and Lake Erie Railroad, which was built and equipped for the transportation of iron ore from Lake Erie to Pittsburg and of coal in the opposite direction.

When this economic proposition was fairly established, it was wonderful to see how railroad managers and capitalists met the situation, by investing additional capital for the newer type of equipment, and for the changes in road bed and location necessarily involved with that in the rolling stock. Curves were taken out or diminished, grades were reduced, heavier rails were laid, and new bridges built, so that practically some lines were almost rebuilt. The process is still going on and money by the hundred millions is involved in the transformation and equipment of the railroads. Some impression of the magnitude of the change in equipment may be gained from the single fact, that one of the leading railroads has within a few years expended more than twenty millions of dollars for new freight cars alone, all of which have a capacity of 100,000 pounds.

The form of loading for bridges almost universally specified by the railroads of this country consists of two consolidation locomotives followed by a uniform train load. These loads are frequently chosen somewhat larger than those that are likely to be actually used for some years in advance, but sometimes the heaviest type of locomotives in use is adopted as the standard loading. The extent to which the specified loadings have changed in eight years may be seen from the following statement based on statistics compiled by Ward Baldwin and published in the *Railroad Gazette* for May 2, 1902.

Of the railroads whose lengths exceed 100 miles, located in the United States, Canada, and Mexico, only 2 out of 77 specified uniform train loads *exceeding* 4,000 pounds per linear oot of track in 1893, while in 1901, only 13 out of 103 railroads

specified similar loads *less* than 4,000 pounds. In 1893, 37 railroads specified loads of 3,000 pounds and 29 of 4,000 pounds, while in 1901, 4,000 pounds was specified by 50, 4,500 pounds by 14, and 5,000 pounds by 17 railroads. The maximum uniform load rose from 4,200 in 1893 to 6,600 pounds in 1901.

In a similar manner in 1893 only 1 railroad in 75 specified a load on each driving wheel axle *exceeding* 40,000 pounds, while in 1901 only 13 railroads out of 92 specified *less* than this load. In 1893 only 21 of the 77 railroads specified similar loads exceeding 30,000 pounds. The maximum load on each driving wheel axle rose from 44,000 pounds in 1893 to 60,000 pounds in 1901.

The unusual amount of new bridge construction required caused a general revision of the standard specifications for bridges, the effect of which was to include the results of recent studies and experiment, and to eliminate some of the minor and unessential items formerly prescribed.

Meanwhile another movement was in progress. Experience having shown the great advantage of more uniformity in various details and standards relating to the manufacture of bridges both in reducing the cost and the time required for the shop work, an effort was begun to secure more uniformity in the requirements for the production and tests of steel, which is the metal now exclusively employed in bridges.

The American Section of the International Association of Testing Materials is bringing together through its investigations and discussions a mass of selected information on the relations of chemical composition, heat treatment, mechanical work, etc., to the physical properties of steel as well as of other metals used in structures and for mechanical purposes.

The thorough digest of these results of scientific research and practical tests, and the preparation and adoption of standard specifications for different classes of material, are confidently expected to eliminate many old requirements which are proven inefficient in securing the results for which they were originally intended, and to incorporate in the specifications only the essential requirements by which the character of the product

may be determined with sufficient precision for its actual duty. By making these requirements reasonable and fair, on the one hand as simple and definite as possible without impairing their real value, and on the other hand flexible enough to avoid imposing undue hardship upon the manufacturer who keeps in touch with the best methods available, the result is confidently expected to be a high degree of interested cooperation on the part of both engineer and manufacturer in securing the best grade of material which the present state of science makes practicable.

The American section of that Association in 1901 adopted a series of proposed standard specifications, one of which relates to steel for bridges and buildings and which is recommended for adoption by those who buy such structures. A committee of the Railway Engineering and Maintenance of Way Association is now at work on the same problem, a full agreement having not yet been reached.

With greater uniformity in the physical, chemical and other requirements for steel, as determined by standard tests, the unit stresses to be prescribed for the design of bridges will naturally approach to a corresponding uniformity. To what extent this is desirable may be inferred from the fact that the application of several of the leading specifications to the design of a railroad bridge under a given live load yields results which may vary by an amount ranging from zero to twenty-five per cent. of the total weight.

In the revision of specifications a decided tendency is observed to simplify the design by making an allowance for impact, vibration, etc., by adding certain percentages to the live load according to some well-defined system. It needs but relatively little experience in making comparative designs of bridges under the same loading, to show the advantage of this method over that in which the allowance is made in the unit stresses according to any of the systems usually adopted in such a case. Not only are the necessary computations greatly simplified but the same degree of security is obtained in every detail of the connections as in the principal members which compose the structure.

Experiments on a large scale are very much needed to determine the proper percentage of the live load to be allowed for the effect of impact, so as to secure the necessary strength with the least sacrifice of true economy. While the extreme economy of material that was formerly practised is not now desirable, since stiffness receives due consideration, some idea of the importance of such an investigation may be gained by considering the magnitude of the industries involved.

In March, the *Railroad Gazette* published a supplement containing a list of bridge projects under consideration. This list was intended to include only the larger steel and stone structures, whether for railroads or highways, the aim being to exclude those that are obviously unimportant. Besides this, the bridges needed on 1,500 new railroad projects recorded in the same supplement are likewise excluded. After excluding both of these classes the list still contains about 1,300 new projects for bridges.

An investigation might also be advantageously made to determine the proper ratio of the thickness of cover plates in chord members which are subject to compression, to the transverse distance between the connecting lines of rivets. The same need exists in regard to the stiffening of the webs of plate girders, concerning which there is a wide variation in the requirements of different specifications.

A movement which has done much good during the past decade and promises more for the future is that of the organization of bridge departments by the railroad companies. The great economy of making one design rather than to ask a number of bridge companies to make an equal number of designs, of which all but one are wasted, is the first advantage; but another of even greater significance in the development of bridge construction is that which arises from the designs being made by those who observe the bridges in the conditions of service and who will naturally devote closer study to every detail than is possible under the former usual conditions. The larger number of responsible designers also leads to the introduction of more new details to be submitted to the test of service, which will indicate those worthy of adoption in later

designs. In order to save time and labor and secure greater uniformity in the design of the smaller bridges, some of the railroads prepare standard plans for spans varying by small distances. For the most important structures consulting bridge engineers are more frequently employed than formerly, when so much dependence was placed upon competitive designs made by the bridge companies.

An investigation was recently made by a committee of the Railway Engineering and Maintenance of Way Association in regard to the present practice respecting the degree of completeness of the plans and specifications furnished by the railroads. It was found that of the 72 railroads replying definitely to the inquiry, 33 per cent. prepare "plans of more or less detail, but sufficiently full and precise to allow the bidder to figure the weight correctly and if awarded the contract to at once list the mill orders for material"; 18 per cent. prepare "general outline drawings showing the composition of members, but no details of joints and connections"; while 49 per cent. prepare "full specifications with survey plan only, leaving the bidder to submit a design with his bid." If, however, the comparison be made on the basis of mileage represented by these 72 railroads, the corresponding percentages are 48, 24 and 28, respectively. The total mileage represented was 117,245 miles. A large majority of the engineers and bridge companies that responded were in favor of making detail plans.

The shop drawings which show the form of the bridge, the character and relations of all its parts, give the section and length of every member, and the size and position of every detail, whether it be a reinforcing plate, a pin, a bolt, a rivet or a lacing bar. All dimensions on the drawings are checked independently so as to avoid any chance for errors. The systematic manner in which the drawings are made and checked and the thorough organization of every department of the shops, makes it possible to manufacture the largest bridge, to ship the pieces to a distant site and find on erecting the structure in place that all the parts fit together, although they had not been assembled at the works.

The constant improvement in the equipment of the bridge

shops, and the increasing experience of the manufacturers who devote their entire time and attention to the study of better methods for transforming plates, bars, shapes, rivets, and pins into bridges, constitute important factors in the development of bridge construction.

As the length of span for the different classes of bridges gives a general indication of the progress in the science and art of bridge building, the following references are made to the longest existing span for each class, together with the increase in span which has been effected approximately during the past decade.

In plate-girder bridges the girders, as their name implies, have solid webs composed of steel plates. A dozen years ago but few plate girders were built whose span exceeded 100 feet, the maximum span being but a few feet longer than this. To-day such large girders are very frequently constructed, and the maximum span has been increased to 126 feet between centers of bearings. This is the span of the large plate girders of the viaduct on the Riverside drive in New York City, erected in 1900. The longest railroad plate girder was erected about the same time on the Bradford Division of the Erie Railroad, its span being 125 feet 2½ inches. The heaviest plate girder is the middle one of a four-track bridge on the New York Central Railroad erected last year near Lyons, N. Y. Its weight is 103 tons, its span 107 feet 8 inches, and its depth out to out 12 feet 2 inches.

The large amount of new construction and the corresponding increase in the weight of the rolling stock have combined to secure a more extensive adoption of plate girders and the designs of many new details for them. These affect chiefly the composition of the flanges, the web splices, the expansion bearings and the solid floor system. Although solid metal floors built up of special shapes were first introduced into this country fifteen years ago, their general adoption has taken place largely within the past decade on account of their special adaptation to the requirements of the elevation of tracks in cities. Solid floors may not only be made much shallower an the ordinary open type, thereby reducing the total cost

of the track elevation, but they also permit the ordinary track construction with cross-ties in ballast to be extended across the bridge, thus avoiding the jar which otherwise results as the train enters and leaves the bridge, unless the track is maintained with extraordinary care.

The necessity for bridges of greater stiffness under the increased live loads has also led to the use of riveted bridges for considerably longer spans than were in use six or seven years ago. The use of pin-connected trusses for spans less than about 150 feet is undesirable for railroad bridges, on account of the excessive vibration due to the large ratio of the moving load to the dead load, or weight of the bridge itself.

While riveted bridges are now quite generally used for spans from 100 to 150 feet, they have been employed to some extent up to 181½ feet. The recent forms of riveted trusses do not, however, conform to the general character of European designs, but embody the distinctively American feature of concentrating the material into fewer members of substantial construction. With but rare exceptions the trusses are of the Warren, Pratt and Baltimore types with single systems of webbing. At a distance where the riveted connections cannot be distinguished, the larger trusses have the same general appearance as the corresponding pin bridges.

The recent examples of viaduct construction with their stiff bracing of built-up members and riveted connections exhibit a marked contrast to the older and lighter structures with their adjustable bracing composed of slender rods. The viaduct which carries the Chicago and Northwestern Railroad across the valley of the Des Moines river, at a height of 185 feet above the surface of the river is 2,658 feet long. It was built in 1901, is the longest double track viaduct in the world, provided those located in cities be excluded, and is an admirable type of the best modern construction. The tower spans are 45 feet long and the other spans are 75 feet long. Four lines of plate girders support the two tracks. Along with this viaduct should be mentioned the Viaduct Terminal of the Chesapeake and Ohio Railway at Richmond, Va., whose length including the depot branch is 2.13 miles. A large part of this is not very

much higher than an elevated railroad in cities. The excellent details and clean lines of this substantial structure give it a character which is surpassed neither in this country nor abroad. It may be added that the highest viaduct in this country, and which was rebuilt in 1900, is located seventeen miles from Bradford, Pa., where the Erie Railroad crosses the Kinzua Creek at a height of 301 feet. It has a length of 2,053 feet.

While the elevated railroads which have been built recently also embody many of the characteristics of the best viaduct construction, special study has been given to improve their esthetic effect. The use of curved brackets, of connecting plates whose edges are trimmed into curves so as to reduce the number of sharp angles, and of rounded corners of posts, constitute some of the means employed. The results are seen in the structures of the Boston Elevated Railroad and in some of the latest construction in Chicago.

The longest span of any simple truss in America is that of the bridge over the Ohio river at Louisville, erected in 1893. Its span center to center of end pins is 546½ feet. Since that time several other bridges of this kind have been built which are considerably heavier, although their spans are somewhat shorter. The most noteworthy of these are the Delaware River bridge on the Pennsylvania Railroad near Philadelphia and the Monongahela River bridge of the Union Railroad at Rankin, Pa., both of which are double-track bridges. The Delaware River bridge was erected in 1896, each one of its fixed spans having a length of 533 feet and containing 2,094 tons of steel. The Rankin bridge was erected in 1900. Its longer span has a length of 495 feet 8⅛ inches between centers of end pins and contains about 2,800 tons of steel, making it the heaviest single span ever erected. It may also be added that the locomotive and train load for which this bridge was designed is the heaviest that has yet been specified.

The recent changes in the details of pin-connected truss bridges have been mainly the result of efforts to eliminate ambiguity in the stresses of the trusses, to reduce the effect of secondary stresses, and to secure increased stiffness as well as strength in the structure. Double systems of webbing have

been practically abandoned so far as new construction is concerned. The simplicity of truss action thus secured permits the stresses to be computed with greater accuracy and thereby tends to economy. Before the last decade very few through bridges and those only of large span were designed with end floor beams in order to make the superstructure as complete as possible in itself and independent of the masonry supports. Now this improved feature is being extended to bridges of small spans. Similarly dropping the ends of all floor beams in through bridges so as to clear the lower chord and to enable the lower lateral system to be connected without producing an excessive bending moment in the posts has likewise been extended to the smaller spans of pin bridges and is now the standard practice. The expansion bearings have been made more effective by the use of larger rollers, and of bed plates so designed as to properly distribute the large loads upon the masonry. In the large spans of through bridges the top chord is curved more uniformly, thereby improving the esthetic appearance. These chords are also given full pin bearings, thus reducing the secondary stresses.

The stiffness of truss bridges has been secured by adopting stiff bracing in the lateral systems and sway bracing, instead of the light adjustable rods formerly used. At the same time adjustable counter ties in the trusses are being replaced in recent years by stiff ones, while in some cases the counters are omitted and the main diagonals designed to take both tension and compression.

Some of the same influences referred to above have led to much simpler designs for the portal bracing by using a few members of adequate strength and stiffness similar in general character to those of the trusses.

Such steady progress in the design and construction of railroad bridges of moderate span has, unfortunately, no adequate counterpart in highway bridges. The conditions under which highway bridges are purchased by township and county commissioners are decidedly unfavorable to material improvements in the character of their details. It is a comparatively rare occurrence that the commissioners employ a bridge en-

gineer to look after the interests of the taxpayers by providing suitable specifications, making the design, inspecting the material, and examining the construction of the bridge to see that it conforms to all the imposed requirements. These provisions are only made in some of the cities, and accordingly one must examine the new bridges in cities to learn what progress is making in highway bridge building.

The lack of proper supervision in the rural districts and many of the smaller cities results in the continued use of short trusses with slender members built up of thin plates and shapes, whose comparatively light weight causes excessive vibration and consequent wear, as well as deterioration from rust. Under better administration plate girders would be substituted for such light trusses, making both a stiffer structure and one more easily protected by paint. The general lack of inspection and the consequent failure to protect highway bridges by regular repainting will materially shorten their life and thereby increase the financial burden to replace them by new structures. Some progress has been made in adopting riveted trusses for the shorter spans for which pin-connected trusses were formerly used, but the extent of this change is by no means as extensive as it should be, nor equal to the corresponding advance in railroad bridges.

The channel span of the cantilever bridge over the Mississippi River at Memphis, Tenn., is the longest one of any bridge of this class in America. It measures 790½ feet between centers of supports. This bridge was finished in 1892, or only two years after the close of the seven-year period of construction and erection of the mammoth cantilever bridge over the Firth of Forth in Scotland. A number of cantilever bridges have been built since then, but most of them have comparatively short spans. There is one now under construction over the Monongahela River in Pittsburg, and which is expected to be finished this year, whose span is to be a little longer than that of the Memphis bridge. It is on the new extension of the Wabash Railroad system, and the distance between pier centers is 812 feet.

But there is another one being built which will not only

have a longer span than any other cantilever bridge in this country, but longer than that of any other bridge whatsoever. It is located near Quebec, Canada, and its channel span over the Saint Lawrence River is to have the unprecedented length of 1,800 feet or nearly a hundred feet longer than that of the Forth cantilever bridge and two hundred feet longer than the Brooklyn suspension bridge. The towers will have a height of 360 feet above high tide. It will accommodate a double-track railroad, besides two electric railway tracks and highways. In the piers the courses of masonry are four feet high and individual stones weigh about fifteen tons each. The character of its design and the simplicity of its details will permit its construction with unusual rapidity and economy for a bridge of this magnitude. Several other cantilever structures whose largest spans range from 600 to 671 feet are either now or soon will be under construction.

The Brooklyn bridge, completed in 1883, is still the largest suspension bridge in the world, its span being 1,595½ feet. More people cross this bridge than any other in any country. The New East River bridge, which is now being built, has a span of 1,600 feet, and its capacity will be very much greater than that of the Brooklyn bridge. Each of its four cables has a safe strength of over 10,000,000 pounds in tension.

One of the most interesting developments relating to the subject under consideration is the construction of a considerable number of metallic arch bridges in recent years and the promise of their still greater use in the future. On account of their form they constitute one of the handsomest classes of bridges.

The first important steel bridge in the world was completed in 1874. It is the arch bridge which in three spans crosses the Mississippi River at St. Louis. Its arches are without hinges and their ends are firmly fixed to the piers. This is one of the most famous bridges in existence. For a long time after its construction no metallic arches were erected in this country, although many were built in Eu-

rope. In 1888, however, the highway bridge across the Mississippi River at Minneapolis was erected, consisting of two spans of 456 feet each and which still remains the longest span of any three-hinged arch. The following year the Washington bridge over the Harlem River in New York City was completed. It consists of two spans of 510 feet in the clear and has the largest two-hinged arch ribs with solid web plates.

These were followed by a number of arches of various types, the most noted of which are the two arch bridges over the Niagara River. The first one is a spandrel-braced, two-hinged arch with a span of 550 feet and replaced the Roebling suspension bridge in 1897 It accommodates the two tracks of the Grand Trunk Railroad on the upper deck and a highway on the lower deck. The other bridge has arched trusses with parallel chords and two hinges. It replaced the Niagara and Clifton highway suspension bridge in 1898, and as its span is 840 feet, it is the largest arch of any type in the world. The manner in which this arch was erected furnishes an illustration of the effort which is made by engineers to conform the actual conditions so far as possible to the theoretic ones involved in the computation of the stresses. Since the stresses in an arch having less than three hinges are statically indeterminate, stresses of considerable magnitude may be introduced into the trusses if the workmanship be imperfect, the supports not located with sufficient precision, and the arch closed without the proper means and care.

The Niagara and Clifton arch was first closed as a three-hinged arch and then transformed into a two-hinged arch by inserting the final member under the sum of the computed stress due to the weight of the truss, and that due to the difference between the temperature at which the closure was made and that assumed as standard in the stress computations. This stress was secured in the member by inserting it when the hydraulic jack which forced apart the adjacent ends of the shortened chords registered the required amount of pressure. The arch had been erected

as a pair of cantilevers from each side extending 420 feet out beyond the supports, and when the closure was made the two arms came together within a quarter of an inch of the computed value. Such a result involving the "accuracy of the calculation and design of the entire steel work, the exactness with which the bearing shoes or skewbacks were placed, and the perfection of the shopwork" has been truly characterized as phenomenal.* In order to reduce secondary stresses to a minimum the members were bolted up during the cantilever erection and the bolts replaced by rivets after the closure of the arch rib.

The past decade witnessed the introduction and extensive development of arches of concrete and of concrete-steel construction. In the latter kind a small amount of steel is imbedded in the concrete in order to resist any tensile stresses that may be developed. During this period more than 150 concrete steel bridges have been built in this country. In the same year in which the largest metallic arch was completed, the five concrete-steel arches of the bridge at Topeka, Kansas, were finished. The largest one has a span of 125 feet and still remains the largest span of this type in America, although it has been exceeded in Europe. Considerably larger spans are to be built this season, while others are included in the accepted design for the proposed Memorial bridge at Washington.

It is the smaller steel structures which are destined more and more to be replaced by arches of this material. The steel bridges require repainting at frequent intervals, constant inspection, occasional repairs and finally replacing by a new structure after a relatively short life, on account of rust and wear, unless it is required even sooner on account of a considerable increase in the live load. The concrete arch requires practically no attention except at very long intervals.

The safety of operating the traffic makes it desirable to have as few breaks as possible in the regular track construction of a railroad, and this constitutes an additional reason why con-

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crete or stone arches are being substituted for the smaller openings. The decreasing cost of concrete tends to an extension of this practice to openings of increasing size. Last year, however, a bridge was completed which marks a decided departure from previous practice. The Pennsylvania Railroad built a stone bridge, consisting of 48 segmental arches of 70 feet span, at the crossing of the Susquehanna River at Rockville, Pa. It is 52 feet wide, accommodates four tracks, and cost a million dollars. This bridge has not only the advantage of almost entirely eliminating the cost of maintenance, but it also has sufficient mass to withstand the floods which occasionally wreck the other bridges on that river. This year the same railroad is building a similar bridge over the Raritan River at New Brunswick, N. J.

Of movable bridges the largest swing span existing was erected in 1893 at Omaha over the Missouri River, its length being 520 feet. Two years later a four-track railroad swing bridge was built by the New York Central Railroad over the Harlem River in New York city, which is only 389 feet long between centers of end pins, but which weighs about 2,500 tons and is accordingly the heaviest drawbridge of any class in the world.

During the past decade a remarkable development was made in drawbridge construction by the modification and improvement of some of the older types of lift bridges and the design of several new types. At South Halstead Street a direct-lift bridge was built in 1893 over the Chicago River, in which a simple span 130 feet long and 50 feet wide is lifted vertically 142½ feet by means of cables to which counterweights are attached. Formerly, only very small bridges of this kind were used, as those, for instance, over the Erie Canal.

In 1895 a rolling lift bridge over the Chicago River was completed. In this new design as each leaf of the bridge rotates to a vertical position it rolls backward at one end. When closed the two leaves are locked at the center, but they are supported as cantilevers. This form has been found to have so many advantages for the crossings of relatively narrow streams, where an unobstructed water way is required and the adjacent shores are needed for dock room, that a score of im-

portant structures of this class have been built in different cities. The largest span that has been designed is 275 feet between centers of supports, while the widest one is to accommodate eight railroad tracks crossing the Chicago Main Drainage Canal.

About the same time and under similar conditions another type of bascule bridge was built at Sixteenth Street, Milwaukee, in which, as each leaf moves toward the shore, one end rises and the other falls, so that its center of gravity moves horizontally, thus requiring a very small expenditure of power to operate the bridge.

Several improved forms of hinged-lift bridges have also been designed and built in Chicago and elsewhere. In a small bridge erected in 1896 on the Erie Railroad in the Hackensack meadows there is only a single leaf hinged at one end and lifted by a cable attached to the other end. The counterweight rolls on a curved track so designed as to make the counter balance equally effective in all stages of opening or closing the bridge.

A novel bridge is now being built over the ship canal at Duluth which is different from any other type in this country. The general scheme is similar to that of a design made by a French engineer who built three of the structures in different countries. It consists of a simple truss bridge 393 feet 9 inches long, supported on towers at a clear height of 135 feet above high water. Instead of supporting the usual floor of a highway bridge it supports the track of a suspended car which is properly stiffened against wind pressure and lateral vibration, the floor of the car being on a level with the docks. This ferry is operated by electricity. The loaded car, its hangers, trucks and machinery weigh 120 tons. In the French design a suspension bridge was used instead of the simple truss bridge.

A bridge is being built across the Charles River between Boston and Cambridge that deserves especial mention and marks a decided advance in the growing recognition on the part of municipal authorities of the importance of esthetic considerations in the design of public works. It consists of 11 spans of steel arches whose lengths range from 101½ to 188½ feet. Its width is 105 feet between railings. It is claimed

that this bridge "will be not only one of the finest structures of its kind in this country, but will be a rival of any in the old world." Its length between abutments is 1,767½ feet, and it is estimated to cost about two and a half millions of dollars.

The problems incident to the replacing and strengthening of old bridges frequently tax the resources of the engineer and demonstrate his ability to overcome difficulties. Only a few examples will be cited to indicate the character of this work. In 1900 the Niagara cantilever bridge had its capacity increased about 75 per cent. by the insertion of a middle truss without interfering with traffic. In 1897 the entire floor of the Cincinnati and Covington suspension bridge was raised four feet while the traffic was using it. It may be of interest to state that the two new cables, 10½ inches in diameter, which were added to increase the capacity of the bridge, have just about three times the strength of the two old ones, 12⅓ inches in diameter, and which were made a little over thirty years before. In the same year the old tubular bridge across the Saint Lawrence River was replaced by simple truss spans without the use of false works under the bridge and without interfering with traffic. On May 25 of this year the Pennsylvania Railroad bridge over the Raritan River and canal at New Brunswick, N. J., was moved sidewise a distance of 14½ feet. Five simple spans 150 feet long and a drawbridge of the same length, weighing in all 2,057 tons, were moved to the new position and aligned in 2 minutes and 50 seconds. The actual time that the two tracks were out of service were respectively 15 and 28 minutes. On October 17, 1897, on the same railroad near Girard Avenue, Philadelphia, an old span was moved away and a new one, 235 feet 7 inches long, put in exactly the same place in 2 minutes and 28 seconds. No train was delayed in either case.

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SECTION E.

Geology and Geography.

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ADDRESS

BY

CHARLES R. VAN HISE,

VICE-PRESIDENT AND CHAIRMAN OF SECTION E FOR 1901.

THE TRAINING AND WORK OF A GEOLOGIST.

Geology is a dynamic science, subject to the laws of energy. Geology treats of a world alive, instead of, as commonly supposed, a world finished and dead. The atmosphere, or sphere of air, is ever unquiet; the hydrosphere, or sphere of water, is less active, but still very mobile; the lithosphere or sphere of rock, has everywhere continuous although slow motions. The motions of the atmosphere, the hydrosphere, and the lithosphere alike include motions by which the positions of large masses of material are changed, and internal motions, through which the mineral particles are constantly rearranged with reference one to another, and indeed are constantly remade. Furthermore, the molecules and even the atoms which compose the atmosphere, hydrosphere, and lithosphere have motions of marvelous intricacy and speed. These motions of the atmosphere, the hydrosphere, and the lithosphere are all superimposed upon the astronomical motions—the wobbling revolution of the earth about its axis, the revolution of the earth-moon couple about their common center of gravity, the movement of this couple about the sun at the rate of 68,000 miles per hour, the movement of the solar system among other systems. If it were possible for one to fix in space co-ordinates by which to measure these various motions, the movement of an air particle, of a water drop, of a mineral grain, would be seen to be extraordinarily complex.

It is clear that there is every reason to believe that no atom or molecule in the world ever occupies the same absolute position in space at any two successive moments. Indeed, it must have been an extraordinary accident, if a single particle has occupied in all the history of the universe exactly the same position that it has occupied at any previous time. No such thing as rest for any particle of matter anywhere in the earth or in the universe is known. On the contrary, everywhere all particles are moving in various ways with amazing speed.

No science is independent of other sciences, but geology is peculiar in that it is based upon so many other sciences. Astronomy is built upon mathematics and physics. Chemistry and physics to a considerable degree are built upon each other. Physics also requires mathematics. Biology demands a limited knowledge of physics and chemistry. However, it cannot be said that a knowledge of the basal principles of more than one, or at most two, other sciences is an absolute prerequisite for a successful pursuit of astronomy, chemistry, physics or biology. This is not true of geology. In order to go far in general geology one must have a fair knowledge of physics, chemistry, mineralogy and biology. These may be called the basal sciences of geology. Certain lines of geology the additional sciences, mathematics, astronomy and metallurgy, are very desirable.

Geology treats of the world. In order to have more than a superficial knowledge of geology, it is necessary to know about the elements which compose the world, how force acts upon these elements, what aggregates are formed by the elements and forces, and how life has modified the construction of the world. Chemistry teaches of matter; how it is made up, both in life and in death. Without an understanding of its principles we cannot have an insight into the constitution of the earth or of any part of it. Physics teaches of the manner in which the many forms of that strange something we call force acts upon matter. Without a knowledge of its principles we can never understand the transformation through which the world has

gone. The elements which compose the earth are combined under the laws of physics and chemistry into those almost lifelike bodies which we call minerals. The minerals are commingled in various ways in the rocks. Without a knowledge of mineralogy no one can have even a superficial understanding of the constitution of rock masses. Biology teaches of the substances alive upon the earth. Life is one of the most fundamental of the factors controlling the geological transformations within the superficial belt of weathering; it has acted as the greatest precipitating agent in the sea. Life has had, therefore, a profound and far-reaching effect in determining the nature of the sedimentary formations.

The sciences of chemistry, physics, and biology have been built up by a study of a minute portion of the world. If geology or a science of the earth, is to be constructed, it must apply to the earth as a whole the principles which have so enlightened us as to the nature and relations of the fractions of the world which we observe and handle in our laboratories of physics, chemistry, and biology.

It thus appears that geology is a composite science. It might in a certain sense be called an applied science. Indeed I have often defined geology as the application of the principles of astronomy, of physics, of chemistry, of mineralogy, and of biology to the earth.

Certainly the earth is the single enormous complex aggregate of matter directly within the reach of man. This highly composite earth is the joint result of astronomical, physical, chemical, and biological forces, working upon matter on an incomparably vaster scale than can ever be imitated in our laboratories. A study of these stupendous results has already advanced at many points astronomy, physics, chemistry, and biology; and future studies made with direct reference to the causes which have produced this wonderful earth are sure to lead to even greater advances in these sciences.

If geology is to become a genetic science, or, more simply. is to become a science under the laws of energy. geology in

large measure must become aquantitative science. In the past it has been too frequently true that because a single force or agent working in a certain direction is a real cause of a phenomenon, the conclusion is drawn that it is a sufficient cause. Only occasionally has the question been asked, "Is this real cause an adequate cause?" Very often differences of opinion have arisen between geologists, one holding that this cause is the one which explains the phenomenon, another holding that that is the explanation, and each insisting that the other is wrong. In such cases very rarely is the question asked whether the explanations offered are *contradictory* or *complementary*. In many cases the explanation is not to be found in one cause, but in several or many, and thus frequently the conclusions which have been interpreted to be contradictory are really supplementary. To illustrate: but few writers have assigned more than a single cause for crustal shortening. One has held that secular cooling is *the* cause; another has given a different cause, and has held that secular cooling is of little consequence. But it is certain that secular cooling, vulcanism, change of oblateness of the earth, change of pressure within the earth, changes of form of the material of the earth, and various other causes, are not exclusive of one another, but are all supplementary. The ability to perceive the supplementary nature of various explanations offered for a phenomenon is one of the most marked, perhaps the most marked, of the characteristics of the superior man. The new geology must not only ascertain all of the real causes for crustal shortening, and other phenomena, but in order satisfactorily to solve the problems of geology it must determine the quantitative importance of each. Geology within the next few years is certain to largely pass to a quantitative basis.

If I have correctly stated the relations of geology to the other sciences, it follows as a corollary that those only can greatly advance the principles of geology who have a working knowledge of two or more of the sciences upon which it is based.

By a working knowledge of a science I mean such a knowledge of its principles as makes them living truths. One must not only be able to comprehend the principles, but he must see them in relation to one another; must be able to apply them. It is not sufficient for a carpenter to be able to explain how the hammer and saw and plane and chisel work; he must be able to use them. He must be able to hit the nail on the head, to cut straight, to plane smooth, to chisel true, and to do all upon the same piece of timber so as to adapt it to a definite purpose in a building. Just so the geologist must be able to apply as tools the various principles of physics and chemistry and biology and mineralogy to the piece of work upon which he is engaged; and thus shape his piece to its place in the great structure of geological science. This is what is meant by a working knowledge of the sciences basal to geology.

It is not supposed that any one man has a comprehensive knowledge of all the basal sciences, or even a working knowledge of their principles; but such knowledge he must have of two or more of them if he hopes to advance the principles of geology. He will be able to handle those branches of his subject with which he deals in proportion as he has a working knowledge of the basal sciences upon which his special branch is based, and will probably correlate this branch with the other branches of the great subject of geology in proportion as his working knowledge of the basal sciences is extensive.

For instance, to advance geological paleontology one must have a working knowledge of the principles of biology and of stratigraphy. To advance any of the lines of physical geology, one must have a working knowledge of the principles of physics, and especially of elementary mechanics. To advance physiography one must have a working knowledge of physics and chemistry. To advance knowledge of the early history of the earth, one must not only have a working knowledge of physics and chemistry, but of astronomy. To advance petrology, one must have a working knowledge of physics, chemistry and mineralogy. To ad-

vance the theory of ore deposition or metamorphism, one must know not only the principles of physical geology, with all which that implies, but he must have a working knowledge of chemistry, physics, mineralogy, and petrology. It is unnecessary to add that a geologist must be able to read some of the modern languages, and be able to express himself clearly and logically in one language.

Considering the breadth and thoroughness of the necessary preliminary training for the sucessful pursuit of geology, one might anticipate that geology would suffer but little from pseudo-scientists. But this anticipation is based upon the idea that no one attempts geological work, and especially to write geological papers, until he is prepared to do so. All sciences have their cranks. Many a little town has "its philosopher" who believes that all of the principles of astronomy, of physics, of chemistry, which have been discovered by the great men of the past are absolutely erroneous, and who makes a new start upon the construction of the world, building in his brain strange vagaries which have no relation to the facts of the universe. While there are temptations to pseudo-scientific work in all sciences, the temptation is nowhere so great as in geology. The planets, sun, and stars are far off; the elements are elusive; to do anything with force one must have at least seen the inside of a physical labaratory; the manner of the transformations of living forms is not obvious, or even apparently so, and few write about the constitution of plants and animals who have not closely studied them. But one is born upon the earth; he lives upon the earth; he sees the surrounding hills and valleys. The dullest sees something of the transformations going on. Many naturally become interested in the phenomena of the earth, and without preparation think that they are able to make important contributions to the science of geology. Thus not only in every city, but in many villages, is a geologist of local repute who has ready explanations for the order of the world.

Geology starts as an easy observational study, and gradually becomes more and more complex until it taxes the master mind

to the utmost. This easy start leads to the multitude of local geologists, but geology suffers comparatively little from them. The real injury which the science receives is from some of those who call themselves professional geologists, are teachers of geology in academies and colleges, or are even members of the staff of official surveys. These men have gone further than the local geologist; but perhaps they have been led into geology for somewhat the same reason, by its easy start as an observational science. A man may begin his career as a geologist by making a few observations here and there and giving a guess as to their meaning. With this beginning he becomes more and more interested, until finally he decides to make geology his profession.

In some cases following this decision the necessity is seen for obtaining a working knowledge of the basal sciences. But too often men who have entered upon geological work have received no adequate training in chemistry, in physics, in biology, and therefore at the outset wholly lack the tools to successfully handle the phenomena which they observe. Such inadequately trained men feel that a satisfactory explanation of any phenomenon must include a statement of the chemical or physical or biological principles involved. In such cases it is safe to say that the explanations given are extremely partial, including only a modicum of truth, and more often than not are absolutely fallacious. Indeed, no other result can be expected from one who lacks a working knowledge of the principles of physics, chemistry, and biology. Occasionally there is a clear-sighted, capable man, lacking in adequate training, who does important geological work simply because he knows his limitations, and there stops. But this is very exceptional indeed, and the physical explanations offered by many for various geological phenomena are no less than grotesque.

It has been made plain that a working knowledge of the sciences basal to geology is necessary in order to advance its principles. But I go even further, and hold that such basal knowledge is absolutely necessary in order to do even good *descriptive* work. Suppose a man to be standing before some complex geological phenomenon The whole intricate inter-

woven story is engraved upon the retina of his eye with more than photographic accuracy. The image on the retina is absolutely the same in the eye of this experienced geologist and in that of a child. Yet if the child be asked to state what he sees his statements will be of the most general kind and may be largely erroneous. The experienced geologist with a knowledge of the principles of physics and chemistry and biology interprets the phenomena imaged in terms of these subjects. The engraving on his retina is the same as on the retina of the child, but his brain perceives the special parts of the picture of interest to him in their true proportions. He understands what is important, what is unimportant; he must select and record the things which are important. If he attempted to record all that is imaged in his eye, a notebook would be filled with the phenomena to be described at a single exposure, and yet half the story would not be told. Good descriptive work is discriminative. Good descriptive work picks out certain of the facts as of great value, others of subordinate value, and others of no value for the purposes under consideration. How then can this discrimination be made? How can the facts be selected which are of service? Only by an insight into the causes which may have produced the phenomena. Without this insight, to some extent at least, a description is absolutely valueless. So far as the geologist has such insight, his description is valuable.

It is frequently urged in opposition to the above that, if a person has theories in reference to the phenomena which he observes his descriptions will be erroneous; he will be biased by his theories. Unfortunately in many cases this is so; but just so far as it is true, the man fails of the qualities which make a successful geologist. One's theories undoubtedly control in large measure the selection of the phenomena which are to be noted, and the wisdom of the selection is a certain criterion of the grade of the geologist. But whatever the facts selected for record, the statement of them should be absolutely unbiased by the theories. Invariably, good practice requires that the statement of facts and the explanation of these facts shall be sharply separated. Doubtless each geol-

ogist who is listening has at different times had different ideas about the same locality, or while away from a locality a new idea has come to him as to the meaning of the phenomena there observed. Upon returning to the old locality with the new idea, additional observations of value have been made, but all the statements of facts made at the previous visits should be found to be absolutely true. In so far as they are untrue, the geologist fails of accuracy, the first fundamental of good observation. If the previous observations are found to be largely erroneous, the man who made them has small chance to become a good geologist. The difference between *bad* observation and *good* observation is that the former is *erroneous;* the latter is *incomplete*. Unfortunately in many cases not only the observations recorded by many men are absolutely false, but they are so intertwined with the theories of the authors that one is unable to discriminate between what is intended to be fact and what is advanced as opinion. It is needless to say that the cases of such men are hopeless; that there is no possibility that they will ever become geologists. I conclude, therefore, that in order to have a standing in the future, even as a descriptive geologist, one must interpret the phenomena which he observes in terms of the principles of astronomy, physics, chemistry, mineralogy, and biology.

If my statement thus far be true, the outline of the training of a man hoping to become a professional geologist is plain. Such a man should take thorough and long courses in each of the subjects of astronomy, physics, chemistry, mineralolgy and biology. This means that a large part of the training of a geologist is the study of the sciences upon which geology is founded. If a man who hopes to be a geologist is wholly lacking in a knowledge of any of the basal sciences, this defect he can probably never make good. Even if he so desires, the time cannot be found. Moreover, chemistry, physics, mineralogy, and biology are laboratory sciences and can be satisfactorily handled only in the laboratory. If the fundamental work in the basal subjects has been done in the college or university, one may keep abreast of their progress during later years; but in order to do this, the basal principles must have become liv-

ing truths to him while a student. If a personal illustration be allowable, during the past five years, in order to handle the problems of geology before me, I have spent more time in trying to remedy my defective knowledge of physics and chemistry and in comprehending advances in these sciences since I was a college student, than I have spent upon current papers in geology, and with, I believe, much more profit to my work. If one has a working knowledge of the basal sciences and lacks training in some branch of geology, this defect he may remedy, for he has the foundation upon which to build. But if he lacks knowledge of the primary principles of the basal sciences he is likely to be a cripple for life, although this is not invariably the case. There are conspicuous instances where lack of early training in the basal sciences has been largely remedied by unusual ability and industry, but this has been most difficult. We should see to it that the young men trained in our colleges and universities, upon whom we place the degree of doctor in geology, are not crippled by the necessity of making good in later life defective basal training. Any university which gives a man the degree of doctor in geology with a defective knowledge of the basal sciences is wronging the man upon whom the degree is conferred; for this man has a right to expect that his courses shall have been so shaped as to have given him the tools to handle the problems which will arise in his chosen profession.

It is not necessary that all of the basal work shall be done before a man begins his life work, but at least a large part of this work should have been done before a man is given the certificate that he can do the work of a professional geologist. But in any case studies in the basal sciences should not cease when the professional degree is granted. Continued studies not only in the basal subjects but in cognate branches and even those far removed from science should continue through life. The geologist finds that however broad and deep his studies are in basal and cognate subjects, he is continually limited by lack of adequate knowledge of them.

In recent years it has been a moot question in colleges and universities as to when specialization should begin, rather

implying that when specialization begins broadening studies should cease. And, indeed, it is upon this hypothesis that most of the discussion upon this subject has been carried on. Some have held that specialization should not begin until late in the college course, or even rather late in the post-graduate course. Others have held that one should early direct his studies to the special subjects which he expects to pursue, and give comparatively little time to other subjects. The argument for this latter course is that competition is now keen, and if a man keeps in the race he must begin to specialize early. It appears to me that both of these answers are inadequate. My answer to the question is that specialization should begin early, but that broadening studies should *not* be discontinued. This rule should obtain not only through the undergraduate course, but in the postgraduate work and during professional life. The specialized work will be better done because of the broad grasp given by the other subjects. The broadening studies will be better interpreted because of the deep insight and knowledge of a certain narrow field. Thus each will help the other. No man may hope for the highest success who does not continue special studies and broadening studies to the end of his career.

But is it held that a geologist lacking an adequate working knowledge of basal studies cannot perform useful service? No, the domain of geology is so great, the portion of the earth not geologically mapped and the structure not worked out is so vast, the ore and other valuable deposits which have received no study are so numerous, that there is an immense field for the application of well-established principles. In geology, as in engineering and other applied sciences, there is an opportunity for many honest, faithful men to perform useful service to the world even if their early training and capacity are not all that could be desired. But even the application of old principles to new areas will be well done in proportion as the geologist has training in the basal sciences; and to the man who combines with such training talent must necessarily be left the advancement of the philosophy of geology. The philosophy of geology, the inner meaning of phenomena, was

the paramount consideration to Hutton and Lyell and Darwin. To them facts were useful mainly that they might see common factors, the great principles which underlie them, or, in other words, generalization. To correctly generalize in geology involves the capacity to hold a vast number of facts in the mind at the same time; to see them in their length and breadth and thickness; to see them at the same time as large masses and as composed of parts, even to the constituent mineral particles and the elements; to see the principles of physics and chemistry and mineralogy and biology running through them. Only by holding a multitude of facts and principles in one's mind at the same time can geology be reduced to order under general laws.

Failure thus to hold in one's mind a large number of facts and principles leads to lack of consistency. Often in a book or a chapter, or on one page, or even in a single paragraph or sentence, are contained ideas which are exclusive of one another. They are not seen by the writer to be exclusive of one another because he is so lacking in a command of the principles of the basal sciences that he is not aware of the antagonism. Major Powell once said to me, "The stage of the development of the human mind is measured by its capacity to eliminate the incongruous." If this hard criterion were rigidly applied, it would follow that many of our profession have not passed the youthful stage. The man who can insert in the same treatise, chapter, or page incongruous ideas saves an immense amount of cerebral tissue for himself. Such a man can write on through chapters and books, and not find it necessary to go back to adjust and interrelate the various parts. There is no action and reaction between the multitude of ideas. The writer has the easy task of holding in his mind at any one time but a few data. He is in delightful and happy unconsciousness of the fact that many of his statements destroy one another. But the man who sees the phenomena and the principles of geology applicable to a case in all their complex relations and true proportions, and who tries to place his fragment of the science in proper relations to other departments of geology and other branches of knowledge has

a task before him requiring great mental effort. He must see phenomena in three dimensions. At every point he must see numerous lines of cause and effect radiate and converge upon the phenomena he is considering from many other phenomena. Of course all fail to do this completely in reference to any complex problem. All fail to reach complete truth. To do this would require infinite capacity. But in so far as success would be attained, the effort must be made. In proportion as one can hold many facts and principles and see their interrelations he will be able to advance the philosophy of geology. This is the work which burns the brain.

And his results he must express in language, the chief means of communicating ideas and relations. Yet language is linear. By figures, models, maps, and other illustrations, wisely used, one may to an important degree remedy the defects of linear language. Yet language and illustration, even when used to the best advantage, but poorly convey one's ideas. Most conscientious writers require as much or more time to put a complex subject into words and illustrations ready for publication as they do in working out the results.

But upon the other side, and in favor of expression in language, it should be remembered that there is action and reaction between one's ideas and the attempt to express them in words and illustrations. The necessity for expression in language is often a wonderful clarifier of ideas. The ideas are improved by the attempt at expression and the expression is continually improved as the ideas are enlarged.

That the difficulty as to expression does not apply to geology alone is well illustrated by the vast amount of labor Charles Darwin spent in putting into the linear form of language the most revolutionary work of the time, "The Origin of Species." It seemed as if the intricately interrelated facts of life were of so complex a nature that language could not handle the problem. But the genius of Darwin was such that he not only proved the truth of a natural origin of species to his own mind, but he so marshaled his facts and principles in linear form in one volume that men were forced to believe. Many of the ideas contained in single sentences or para-

graphs of the "Origin" have been expanded into papers, volumes or treatises by others; and thus made easier to comprehend. The "Origin of Species" has often been said to be a difficult book to read. So it is, because its ideas are more complex than language can easily convey. Darwin unquestionably saw deeper than he was able to express; and it was the struggle to state what he knew which made the writing of the "Origin" such an onerous task. But geology as a whole is only less complex than life; and many of us in the smaller matters with which we are attempting to deal have felt the impossibility of conveying more than imperfectly the ideas and relations which are in our minds.

In thinking of the marvelous complexity of the phenomena of geology, and seeking for an analogy which might in some measure express this complexity, it seemed to me that the inhabitants of the globe and their intricate relations furnish an approximate illustration. From each individual or family or hamlet or city or metropolis, there go out on foot, by wheel, by wagon, by railway, by vessel, various products, some of them to the remoter parts of the earth. From each center, by letter, telegram, telephone, communications diverge—if the center be a large one, by thousands of lines. To each center, materials and thoughts in a like manner converge. In a similar way one class of geological phenomena is related to nearly all other classes. They are related as to their material parts, as to the forces and agents acting, and as to principle concerned in their production. For instance, an economic geologist will appreciate that the development of an ore deposit depends upon the nature of adjacent rocks, upon earth movements, upon the resultant deformation, upon fractures, upon vulcanism, upon erosion by water and ice and wind, upon the circulation of underground water, and upon other complex physical and chemical conditions. One who hopes to gain even an approximately adequate idea of the genesis of an ore deposit, and an insight as to what is probably beyond the point where the deposit is "shown up," must be able to handle the intricate principles of geology. In so far as a geological expert is a master of these, he rises in his profession. In so

far as knowledge of facts and principles is meager, an ore deposit seems a lawless thing which can be dealt with only on the relatively simple principle of the doctrine of chances. If an ore body happens to be found at any place, follow it. If for some unknown reason it is lost or depreciates in value, prod the ground in all directions, up and down, to the right and left, in the blind hope that chance may find more ore. In many cases nine-tenths of this expensive chance work would have been known in advance to be wasted, had the man in charge had a fair knowledge of the geology of the region and of the principles controlling the deposition of ores.

If my statement thus far be founded on truth, the training of a geologist is a valuable one from an intellectual point of view. It is the fashion for professors in all departments of learning each to hold that a knowledge of his subject is necessary for a liberal education. I have heard each of half a dozen professors, representing the classics, history, economics, English, and other subjects, in a single evening each prove to his own satisfaction that his subject is essential to a liberal education. And at the present time some universities still hold similar views in reference to certain subjects. The claim that this or that subject is essential to a liberal education shows a lack of breadth and lack of capacity to see things in their proper proportions. No one language or science is essential to a liberal education. But while this is true, it does not follow that this or that subject may not be essential for a particular career. Far be it from my purpose to speak in a derogatory way or to underestimate the value of any line of knowledge. At the present day a man who is trained only in science or only in the humanities has but one hand; that hand may be strong, but the man can never control the affair before him with the power, with the nicety, with which does the man with two hands, one of which is the rich treasures of science, and the other the no less rich and important treasures of the humanities, each doing its part in harmony with corresponding fullness of results. With a fundamental knowledge of both, the scholar of the future may choose as his chief occupation the clear, cold work of science

which meets the needs of the man driven by an irresistible impulse to see deeper into the majestic order of the universe; or he may choose the attractive work of the humanities which will always have more numerous followers bcause of their direct personal interest.

As I have already intimated, I hold that for the best liberal education one must pursue broadening studies from the first to the last, and also that one must begin early to specialize. If this be true, geology may be said to be a desirable part of a liberal education, for it is built upon the whole realm of pure science, *i. e.*, the knowledge, which applies not only to the earth and all it holds, including man, but to the universe as well. Because of the breadth of training combined with specialization required of a geologist, it might be shown that geology is one of the very useful studies in giving a person a sense of proportion, of perspective and, therefore, of relative values—qualities of the first importance in this world. It might be held that the intellectual training of the geologist is of a kind which helps him in dealing with men and things, and, therefore, for handling the world's work. But time does not suffice to develop this part of the subject.

I shall now suppose that a geologist is adequately trained, that he has some power in generalization, and consider what should be his method of work. It is assumed that the young geologist spends a part of each year in the field. This field work should include areal mapping with structural and genetic interpretations. The more widely a young geologist has traveled, the more numerous the excursions in which he has taken part, the better will be his equipment. But no general work such as this can supply the place of systematic mapping. And the more exact the mapping is, the better the training. Very frequently the educational value of the mapping in detail of a small area is underestimated. Indeed, I hold that nothing else can take its place. Moreover, the only sure way to test a geologist is to require him to delineate upon a map and in structural sections the detailed phenomena of the field. For my part I have more confidence in the future of a young geologist who has mapped in detail twenty-five square miles, and has got out of the area much that is in it, than that of

another who has done no detail work, but has run over and written about thousands of square miles. Rarely can the general conclusions of a man who has not done systematic mapping be relied upon. In America there have been conspicuous cases of men calling themselves geologists who have never carefully mapped a square mile. Yet some of these by the undiscriminating have been regarded as leading geologists. And in one or two cases these men have gained a wide hearing. But the systems which they built up had little or no relation to the world, and they disappeared with the death of their authors. A geologist must not only do systematic field work at the outset; he must continue to do such work through the years to a ripened age. Not infrequently a geologist who in early life has done systematic field work, drops this work and continues writing geological philosophy. But this is a precarious course, which sooner or later makes of him what one of our members calls a "closet geologist." It is only by never-ending action and reaction between observation of the complex phenomena of geology in the field and reflection as to the meaning of the phenomena that sure results can be obtained.

While one should spend a part of each year in the field, I suspect that many more discoveries of geological principles are made in the office or in the laboratory than in the field. The cow collects the grass in the meadow, and afterwards lies down to chew the cud and digest the food. So the geologist in the field, in the midst of innumerable facts, collects all he can. His notes are a record of his daily collections; and, if a successful geologist, of his daily imperfect inferences and deductions. But during the eight or nine months of office and laboratory work he has full opportunity for reflection. He is then likely to see more of the common factors of the facts collected; is more likely to see deeper into the underlying principles which explain them. This is still more true of the facts collected in the current and during the previous years. Indeed, in the field the observations of the current year are often too prominent on account of their recency, and it is only after some months have elapsed that they take their true proportion in connection with

observations of previous years. The handling of the material collected not in one year only, but through many years, is *necessarily* done in the office or in the laboratory, and it is only from such large masses of material that broad generalizations can be made.

But the inductions and deductions made in the office and the laboratory during the winter should be tested in the field in the following year in the light of the new ideas. The new ideas should not by a fraction modify the correctness of the observations of the previous years; they should be found as accurate as when made. But observations are always incomplete, and with a new idea one invariably adds valuable observations which were not noted before the idea was available.

I once wrote to a number of the geologists of this and other countries, asking the directions and dips of the dominant cleavages and joints for the various districts and regions of the world with which they were familiar. From only a single geologist did I obtain data of value. Some geologists wrote that they had not time to observe such subordinate phenomena! These men had evidently not learned the principle that the small but numerous agent or force or structure may have as great or greater importance than more conspicuous but less common ones. Darwin should have taught every scientist the principle of the quantitative importance of the numerous small factor when he showed how great is the work of the apparently insignificant earthworm. It seems to me that joints are one of the important phenomena of geology; and this is true whether the point of view be deformation alone, physiography, metamorphism, circulation of ground water, or the genesis of ores.

While the work of each geologist should be based upon thorough field and office work, and thus have an inductive basis, one should not there stop, but should by deduction ever be looking forward. No one ever held more firmly to fact as a basis for induction than Darwin; but also, no man has more successfully by deduction projected beyond his facts than has Darwin. This in biology was a task of extraordinary difficulty. In geology one who has a firm grasp of the principles

of physics and chemistry may be more daring. Their principles if not more definite than the laws of biology, are at least better known and more simple. Therefore, one, after having observed the facts in a district and grasped the principles which explain them for another area, may deduce what are likely to be the facts and their relations in advance of observation. Or, more concretely, after one gets the correct idea as to the meaning of the phenomena for a certain district, he often can tell in advance of observation what he will see, or can find what I call "geology made to order."

There is no better or more severe test of a theory than one's capacity to find geology made to order. If observation of an area shows the facts are not as expected, this is certain evidence that one or more factors in the problem have been omitted and that the theory is inadequate. In so far as the theory is adequate, the geology will be found as anticipated. The reason for this is the very great complexity and delicate adjustment of the phenomena of nature. To illustrate, if the many parts of some complex machine, such as a great printing press, or a chronometer, were scattered far and wide, and then one should gather many of these parts, and try to fit them, he might find that a numerous set of parts fit perfectly. If this were so, he would know to a certainty that these parts are in the correct positions and relations, even if he did not know the relations of these parts to other parts or the purpose of the whole; for so complex and exact is the adjustment that there is but one way to put the numerous parts together. Another set of parts might be found and these made to fit. But doubtless certain parts would not be found. These would be missing links necessary to make a perfect machine. In this situation, if the man had a genius for mechanical construction, and an insight into principles, he might be able to understand the purpose of the whole, and finally to supply the parts which render the whole a useful machine. This he would be likely to accomplish just in proportion as he had mechanical insight.

So the geologist fits together his numerous diverse facts. If he finds a solution of a problem which is in accord with

all the numerous facts observed, he may be sure he is on the right track, even if he is incapable of seeing the full truth, for so delicate is the adjustment of facts that where they are numerous there is usually only one way to put them together. Just in proportion as the man has a working knowledge of the principles of physics and chemistry and biology and the other cognate sciences will he be able to eliminate erroneous explanations, combine the facts into groups under true theories, and correctly infer how the different groups are to be adjusted, how the various facts which seem at first to have no definite relations are related. Or, to put it in another way, in proportion as he knows the rules of the game will he be able to correctly interpret the meaning of phenomena, and from them to project into the unknown. The importance of understanding the rules of the game is not often appreciated. To the person who is ignorant of the principles of the various sciences all things are possible. So many wonderful things have happened within the past half century that he thinks it possible for anything to happen. He has no principles by which he can determine whether or not a statement is probably true. Hence all sorts of grotesque notions flourish. Indeed, the very fact that so many wonderful things have been accomplished makes many more ready to regard as possible almost any absurdity announced by some so-called "professor."

Perhaps at no time in the history of the world have many educated people shown more ready credulity. Indeed, it seems as if the more grotesque and preposterous an idea, the more likely it is to receive attention. And this credulity is not confined to those who are altogether ignorant of science. A man may be a narrow expert in one branch of science and be wholly ignorant of the rules of the game in reference to another science. For instance, when an eminent biologist says "bell-ringing, the playing on musical instruments, stone-throwing and various movements of solid bodies, all without human contact or any discoverable physical cause—still occur among us as they have occurred in all ages,"* the statements show the author to be so lacking in a comprehension of the princi-

*"The Wonderful Century," by Alfred Russell Wallace, p. 211.

ples of physics that he is unable to estimate whether a phenomenon of physics is likely or not likely to be true. It is clear that a man may be an authority as to biology, and yet be so ignorant of the rules of physics that he may be as simple as a child in reference to that subject. Upon the other hand, a man who has a firm understanding of the principles applicable to a case, or, in other words, knows the rules of the game, is likely to be able to reach a rather definite conclusion as to whether an explanation which suggests itself is in accordance with those rules, and therefore may be true, or disagrees with some of the well-established rules, and therefore is not worth considering.

A geologist once said to me of my teacher and early geological guide, Professor Irving, that he was more correct as to the structure of the Lake Superior region than he ought to have been. But I say that every man is just as correct as to deduction beyond observed facts as he should be. Men with defective basal training and mediocre intellect will always fail when they try to put facts together under principles, and especially when they attempt to project by deduction beyond observed facts. But men who have a firm grasp of the principles of the sciences basal to geology, the capacity to correlate these principles and apply them to the facts of geology, will go beyond their observations, and by deduction will with perfect confidence reach conclusions which are far in advance of observation. Indeed in this way only can the best geological work be done. After one has projected his deductions in advance of observations, he returns to the field with these new ideas, and then carries his observations farther than he was able to do before. The geologist whose ideas are not continually outrunning his observations will never go far in the science. He whose mind is behind his observations instead of in advance of them, will ever be mediocre. The minds of the leaders of geology are on the mountain heights before their feet have more than touched the foothills.

The conclusions deduced by a scientific genius may go so far in advance of observations that he who announces the

conclusions may not be able to make observations which confirm the theories during his lifetime. In such cases subsequent observations made through many years by others will find the phenomena confirming the principles. The truths announced by men of insight are often not accepted by slower men until this later observational work is done. Many cases could be cited illustrating these statements. Darwin, in 1860, *knew* that life had existed that would fill in the great gaps in the very imperfectly known paleontological record. Since 1860 all, the greater gaps have been filled by discovered fossils. Mendeléeff, when he saw the law of the periodic arrangement of the elements, *knew* the elements to exist which would fill the gaps, but it took many years of work by many men to find a part of them. During the past few years a half dozen or more of the vacant places have been occupied. Each geologist, each scientist, now as in the past, is just as nearly right as he should be. The scientific seers will ever go far in advance and guide others, even as did the spiritual seers of old.

The scope of these observations doubtless extends beyond geology. Much of what has been said is true of knowledge as a whole, not restricted to one subject. But I shall have accomplished my purpose if what I have said be true of geology; for if my conclusions be well founded, they furnish the basis upon which courses should be laid out leading to degrees in professional geology, and to methods of good geological work in the field and in the office.

PAPERS READ.

THE GEOLOGY OF THE PITTSBURG REGION. BY I. C. WHITE, University of West Virginia, Morgantown, W. Va.

THE LOWER CARBONIFEROUS OF THE APPALACHIAN BASIN. BY J. J. STEVENSON, New York, N. Y.

A NEW METEORITE IRON FROM ALGOMA, KEWANNEE COUNTY, WIS. BY W. H HOBBS, Madison, Wis.

THE METEORITES OF NORTHWESTERN KANSAS. BY OLIVER C FARRINGTON.

THE MOHOKEA CALDERA ON HAWAII. BY C. H. HITCHCOCK, Hanover, N. H.

ELLIPSOIDAL STRUCTURE IN THE PRE-CAMBRIAN BASIC AND INTERMEDIATE ROCKS OF THE LAKE SUPERIOR REGION. BY J. MORGAN CLEMENTS.

VERMILION DISTRICT OF MINNESOTA. BY J. MORGAN CLEMENTS.

THE PACIFIC MOUNTAIN SYSTEM OF BRITISH COLUMBIA AND ALASKA. BY ARTHUR C. SPENCER.

Development of the Southeastern Missouri Lowlands. By C. F. Marbut.

Note.—The above papers were presented through the Geological Society of America, and for more complete accounts of the same see Bulletin G. S. A., Vol. XIII, 1902.

The International Geographic Congress of 1904 under the Auspices of the National Geographic Society. By Gilbert H. Grosvenor, Washington, D. C.

Possible Effects of the Glacial Period upon the Land Levels of Central Asia. By G. Frederick Wright, Oberlin, Ohio.

Recent Geology of the Jordan Valley. By G. Frederick Wright, Oberlin, Ohio.

History of the Discoveries and Discussions Concerning the Glacial Terraces in the Upper Ohio and its Tributaries By G. Frederick Wright, Oberlin, Ohio.

Submerged Valleys in Sandusky Bay. By E. L. Moseley, Sandusky, Ohio.

Some Geological Notes in Honduras, Central America. By J. Francis Le Baron, Cleveland, Ohio.

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THE OCCURRENCE OF LIQUID PETROLEUM HERMETICALLY ENCLOSED WITH QUARTZ CRYSTALS, FROM ALABAMA. BY F. L. STEWART.

RESTORATION OF EMBOLOPHORUS DOLLOVIANUS. BY E. C. CASE, Case School of Applied Science, Cleveland, Ohio.

SYNOPSIS OF THE MISSOURIAN AND PERMO-CARBONIFEROUS FISH FAUNAS OF KANSAS AND NEBRASKA. BY C. R. EASTMAN AND E. H. BARBOUR, Mus. Comp. Zoology, Cambridge, Mass.

PHYLOGENY OF THE CESTRACIONT GROUP OF SHARKS. BY C. R. EASTMAN, Mus. Comp. Zoology, Cambridge, Mass.

ON A COMPLETE SKELETON OF A NEW CRETACEAN PLESIOSAUR, ILLUSTRATED BY PHOTOGRAPHS FROM MOUNTED SKELETONS. BY S. W. WILLISTON, University of Kansas, Lawrence, Kansas.

THE BACUBIRITO METEORITE. BY H. A. WARD, Chicago, Ill.

PALÆONTOLOGICAL NOTES:

(*a*) NOTES ON GASTROPODS.
(*b*) SPIRIFER MUCRONATUS AND ITS DERIVATIVES. BY A. W. GRABAU.

NOTE.—The following papers were presented through the National Geographic Society.

SCIENTIFIC RESULTS OF THE RECENT ERUPTIONS IN THE WEST INDIES. BY ROBERT T. HILL, U. S. Geological Survey. Washington, D. C.

THE MAGNETIC DISTURBANCES DURING THE TIME OF THE RECENT VOLCANIC ERUPTIONS IN MARTINIQUE. BY L. A. BAUER, U. S. Coast and Geodetic Survey. Washington, D. C.

ATMOSPHERIC PHENOMENA IN CONNECTION WITH THE RECENT ERUPTIONS IN THE WEST INDIES. BY A. J. HENRY, U. S. Weather Bureau, Washington, D. C.

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ZOOLOGY.

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VICE-PRESIDENT AND CHAIRMAN OF SECTION F FOR 1901.

THE HISTORY OF ICHTHYOLOGY.

Science consists of human experience, tested and placed in order. The science of Ichthyology contains our knowledge of fishes, derived from varied experience of man, tested by methods or instruments of precision, and arranged in orderly sequence. This science, in common with every other, is the work of many men, each in his own field, and each contributing a series of facts, a series of tests of the alleged facts of others, or some improvement in the method of arrangement. As in other branches of science, this work has been done by sincere, devoted men, impelled by a love for this kind of labor, and having in view, as "the only reward they asked, a grateful remembrance of their work." And in token of this reward it is well sometimes, in grateful spirit, to go over the names of those who made even its slight degree of completeness possible.

We may begin the history of Ichthyology with that of so many others of the sciences, with the work of Aristotle (383-322 B. C.). This wonderful observer recorded many facts concerning the structure and habits of the fishes of Greece, and in almost every case his actual observation bears the closest modern test. These observations were hardly "set in order." The number of species he knew was small, about 115 in all, and it did not occur to him that they needed classification. His ideas of species were those of the fishermen, and the changing vernacular supplied him with the necessary names.

As Dr. Günther wisely observes, "it is less surprising that

Aristotle should have found so many truths as that none of his followers should have added to them." For about 1800 years the scholars of the times copied the words of Aristotle, confusing them by the addition of fabulous stories and foolish superstitions, never going back to Nature herself, "who leads us to absolute truth whenever we wander." A few observations were made by Caius Plinius, Claudius Ælianus, Athenæus, and others. About 400 A. D. Decius Magnus Ausonius wrote a pleasing little poem on the Moselle, setting forth the merits of its various fishes. It was not, however, until the middle of the seventeenth century that any advance was made in the knowledge of fishes. At that time the development of scholarship among the nations of Europe was such that a few wise men were able to grasp the idea of species.

In 1553, Pierre Belon published his little book "De Aquatilibus," in which numerous (110) species of fishes of the Mediterranean were described, with tolerable figures, and with these is a creditable attempt at classification. At about this time Ulysses Aldrovandus, of Bologna, founded the first Museum of Natural History and wrote on the fishes it contained. In 1554, Salviani (1514–1572), a physician at Rome, published "Aquatilium Animalium Historia," with good figures of most of the species, together with much general information as to the value and habits of animals of the sea.

More important than these, but almost simultaneous with them, is the great work of Guillaume Rondelet (1507–1557), "De Piscibus Marinis," later published in French and enlarged under other titles. In this work the different species fairly described are 244 in all, chiefly from the Mediterranean, and the various fables previously current are subjected to severe scrutiny. Recognizable woodcuts represent the different species. Classification Rondelet had none, except as simple categories for purposes of convenience. More than usual care is given to the vernacular names, French and Greek. He closes his book with these words.

"Or s'il en i a qui prennent les choses tant à la rigueur, qui ne veulent rien apparouver qui ne soit du tout parfait, je les prie de bien bon cueur de traiter telle, ou quelque autre his-

toire parfaitement, sans qu'il i ait chose quelconque à redire et la receverons é haut louerons bien vouluntiers. Cependant je scai bien, et me console * * *, avec grand travail * * * qu'on pourra trouver plusieurs bones choses e dignes de louange ou proufit é contentement des homes studieux é à l'honneur é grandissime admiration des tres excellens é perfaits œuvres de Dieu."

And with the many "bones choses" of the work of Rondelet men were long too well satisfied, and it was not until the impulse of commerce had brought men face to face with new series of animals not found in the Mediterranean that the work of the science of fishes was again resumed. About 1640 Prince Moritz (Maurice), of Nassau, visited Brazil, taking with him two physicians, George Marcgrav and Wilhelm Piso. In the great work "Historia Naturalis Brasiliæ," published at Leyden, 1648, Marcgrav described about 100 species all new to science, with a good deal of spirit and accuracy. This work was printed by Piso after Marcgrav's death, and his colored drawings—long afterwards used by Bloch—are in the History of Brazil reduced to small and crude woodcuts. This is the first study of a local fish fauna outside the Mediterranean region, and it reflects great credit on Marcgrav and on the illustrious prince whose assistant he was.

There were no other similar attempts of importance in Ichthyology for a hundred years, when Per Osbeck, an enthusiastic student of Linnæus, published (1757) the records of his Chinese cruise under the name of "Iter Chinensis." At about the same time another of Linnæus' students, Hasselquist, published his "Iter Palestinum," the account of his discoveries of fishes in Palestine and Egypt. More pretentious than these and of much value, as an early record, is Mark Caterby's (1679–1749) "Natural History of Carolina and the Bahamas," published in 1748, with large colored plates, which are fairly correct except in those cases where the drawing was made from memory.

About this time Hans Sloane (1660–1752) published his Fishes of Jamaica; Patrick Browne (1720–1790) wrote on the fishes of the same region, while Father Charles Plumier (1646–

1704) made paintings of the fishes of Martinique, long after used by Bloch and Lacépède. Dr. Alexander Garden, of Charleston, South Carolina, collected fishes for Linnæus, as did also Dr. Peter Kalm, in his travels in the northern parts of the American Colonies.

With the revival of interest in general anatomy, several naturalists took up the structure of fishes. Among these Günther mentions Borelli, Malpighi, Swammerdam, and Duverney.

The basis of classification was first fairly recognized by John Ray (1628–1705) and Francis Willughby (1635–1672), who, with other and varied scientific discoveries, undertook, in the "Historia Piscium," published in Oxford in 1686, to bring order out of the confusion left by their predecessors. This work, edited by Ray after Willughby's death, is ostensibly the work, of Willughby with additions by Ray. In this work 420 species were recorded, 180 of these being actually examined by the authors, and the arrangement chosen by them paved the way to a final system of nomenclature.

Direct efforts in this direction, with a fairly clear recognition of genera as well as species, were made by Lorenz Theodor Gronow, called Gronovius, a German naturalist of much acumen, and by Jacob Theodor Klein (1685–1757), whose work "Historia Naturalis Piscium," published about 1745, is of less importance, not being much of an advance over the catalogue of Rondolet.

Far greater than any of these investigators was he who has been justly called the Father of Ichthology, Petrus Artedi (1705–1734).

He was born in Sweden, was a fellow student of Linnæus at Upsala, and devoted his short life wholly to the study of fishes. He went to Holland to examine the collection of East and West Indian fishes of a rich Dutch merchant in Amsterdam named Seba, and there at the age of twenty-nine he was, by accident, drowned in one of the canals. "His manuscripts were fortunately rescued by an Englishman, Cliffort," and they were edited and published by Linnæus in a series of five parts or volumes.

Artedi divided the class of fishes into orders, and these orders again into genera, the genera into species. The name of each species consisted of that of the genus with a descriptive phrase attached. This cumbersome system, called polynomial was a great advance on the shifting vernacular, which in the works of Artedi, Gronow, Klein and others, it was now replacing. But the polynomial system as a system was of short duration. Linnæus soon substituted for it the very convenient binomial system which has now endured for 150 years, and which, with certain modifications, must form the permanent substructure of the nomenclature in systematic zoology.

The genera of Artedi are in almost all cases natural groups, although essentially equivalent to the families of to-day, a division which in Ichthyology was first clearly recognized by Cuvier.

The following is a list of Artedi's genera and their arrangement:

Order MALACOPTERYGII.

Syngnathus (Pipe-fishes). (4 species.)
Cobitis (Loaches). (3.)
Cyprinus (Carp and Dace). (19.)
Clupea (Herrings). (4.)
Argentina (Argentines). (1.)
Exocœtus (Flying-fishes). (2.)
Coregonus (White-fishes). (4.)
Osmerus (Smelts). (2.)
Salmo (Salmon and Trout). (10.)
Esox (Pike). (3.)
Echeneis (Remoras). (1.)
Coryphæna (Dolphins). (3.)
Ammodytes (Sand Launces). (1.)
Pleuronectes (Flounders). (10.)
Stromateus (Butter-fishes). (1.)
Gadus (Cod-fishes). (11.)
Anarhichas (Wolf-fishes). (1.)
Muræna (Eels). (6.)
Ophidion (Cusk-Eels). (2.)

Anableps (Four-Eyed Fish). (1.)
Gymnotus (Carapos). (1.)
Silurus (Cat-fishes). (1.)

Order ACANTHOPTERYGII.

Blennius (Blennies). (5.)
Gobius (Gobies). (4.)
Xiphias (Sword-fishes). (1.)
Scomber (Mackerels). (5.)
Mugil (Mullets). (1.)
Labrus (Wrasses). (9.)
Sparus (Porgies). (15.)
Sciæna (Croakers). (2.)
Perca (Perch and Bass). (7.)
Trachinus (Weavers). (2.)
Trigla (Gurnards). (10.)
Scorpænia (Scorpion-fishes). (2.)
Cottus (Sculpins). (5.)
Zeus (John Dories, etc.). (3.)
Chætodon (Butterfly-fishes). (4.)
Gasterosteus (Stickle-backs). (3.)
Lepturus (Cutlass-fishes) (= *Trichiurus*). (1.)

Order BRANCHIOSTEGI.

Balistes (Trigger-fishes). (6.)
Ostracion (Trunk-fishes). (22.)
Cyclopterus (Lump-fishes). (1.)
Lophius (Anglers). (1.)

Order CHONDROPTERYGII.

Petromyzon (Lampreys). (3.)
Acipenser (Sturgeons). (2.)
Squalus (Sharks). (14.)
Raja (Rays). (11.)

In all 47 genera and 230 species of fishes were known from the whole world in 1738.

The Cetaceans, or whales, constitute a fifth order, Plagiuri, in Artedi's scheme.

As examples of the nomenclature of species I may quote:

"*Zeus ventre aculeato, cauda in extremo circinata*," This polynomial expression was shortened by Linnæus to *Zeus faber*. The species was called by Rondelet "Faber sive Gallus Marinus" and by other authors as "*Piscis Jovii*." "Jovii" suggested *Zeus*, and Rondelet's name *faber* was the specific name chosen by Linnæus.

"*Anarhichas Lupus marinus nostras*." This became with Linnæus "*Anarhichas lupus*."

"Clupea, maxilla inferiore longiose, maculis nigris carcus: Harengus vel Chalcis Auctorum, Herring vel Hering Anglis, Germanis, Belgis. This became *Clupea harengus* in the convenient binomial system of Linnæus.

The great naturalist of the eighteenth century, Carl von Linné, known academically as Carolus Linnæus, was the early associate and close friend of Artedi, and from Artedi he obtained practically all his knowledge of fishes. Linnæus, the head of the University of Upsala, primarily a botanist, was a man of wonderful erudition, and his great strength lay in the orderly arrangement of things. In his lifetime, his greatest work, the "Systema Naturæ," passed through twelve editions. In the tenth edition, in 1758, the binomial system of nomenclature was first consistently applied to all animals. For this reason, most naturalists use the date of its publication as the beginning of zoological nomenclature, although the English naturalists have generally preferred the more complete twelfth edition, published in 1766. This difference in the recognized starting point has been often a source of confusion, as in several cases the names of species were needlessly changed by Linnæus and given differently in the twelfth edition.

In Linnæus' system (10th and 12th editions), all of Artedi's genera were retained save *Lepturus*, which name was changed to *Trichiurus*. The following new genera were added: Chimæra, Tetraodon, Diodon, Centriscus, Pegasus, Callionymus, Uranoscopus, Cepola, Mullus, Teuthis, Loricaria, Fistu'aria, Atherina, Mormyrus, Polynemus, Amia, Elops.

classification was finally much altered; the Chondropterygia and Branchiostegi (with Syngnathus) being called *Amphibia Nantes*, and divided into "Spiraculis compositis" and "Spiraculis solitariis." The other fishes were more naturally distributed according to the position of the ventral fins into Piscis Apodes, Jugulares, Thoracici and Abdominales. The Apodes do not form a homogeneous group, as members of various distinct groups have lost their ventral fins in the process of evolution. But the Jugulares, the Thoracici and the Abdominales must be kept as valid categories in any natural system.

Linnæus' contributions to Zoology consisted mainly of the introduction of his most ingenious and helpful system of book-keeping. By it naturalists of all lands were able to speak of the same species by the same name in whatever tongue. Unfortunately, ignorance, carelessness, and perversity brought about a condition of confusion. For a long period many species were confounded under one name. This began with Linnæus himself. On the other hand, even with Linnæus, the same species often appeared under several different names. In this matter it was not the system of naming which was at fault. It was the lack of accurate knowledge and sometimes the lack of just and conscientious dealing with the work of other men. No system of naming can go beyond the knowledge on which it rests. Ignorance of fact produces confusion in naming. The earlier naturalists had no conception of the laws of geographical distribution. The "Indies," East or West, were alike to them, and "America" was a sufficiently exact record of the origin of any specimen. Moreover, no thought of the geological past of groups and species had yet arisen, and, without the conception of common origin, the facts of homology had no significance. All classification was simply a matter of arbitrary pigeon-holing the records of forms, rather than an expression of actual blood-relationship. To this confusion much was added through love of novelty. Different authors changed names to suit their personal tastes regardless of rights of priority. *Amia* was altered to *Amiatus* because it was too short a name. *Hiodon* was changed to

Amphiodon because it sounded too much like *Diodon*, and other changes much more wanton were introduced, to be condemned and discarded by the more methodical workers of a later period. With all its abuses, however, the binomial nomenclature made possible Systematic Zoology and Botany, and with the Systema Naturæ arose a new era in the science of living organisms.

In common with most naturalists of his day, the spirit of Linnæus was essentially a devout one. Admiration for the wonderful works of God was breathed on almost every page "O Jehovah! quam ampla sunt opera Tua" is on the title page. of the Systema Naturæ, and the inscription over the door of his home at Hammarby was to Linnæus the wisdom of his life. This inscription read:

"Innocue vivito: Numen adest" (Live blameless: God is here).

The followers of Linnæus are divided into two classes, explorers and compilers. To the first class belonged his own students and others who ransacked all lands for species to be added to the lists of the "Systema Naturæ." These men mostly Scandinavian and Dutch, worked with wonderful zeal, enduring every hardship and making great contributions to knowledge, which they published in more or less satisfactory forms. To these men we owe the beginnings of the science of geographical distribution. Among the most notable of these are Per Osbeck and Frederick Hasselquist, already noted, Otto Fabricius, author of a Fauna of Greenland, Carel Thunberg, successor of Linnæus as head of the University of Upsala, who collected fishes about Nagasaki, entrusting most of the descriptive work to the less skilful hands of his students, Jonas Nicolas Ahl and M. Houttuyn. Martin Th. Brunnich, who collected at Marseilles the materials for his "Pisces Massiliensis," Petrus Forskal, whose work on the fishes of the Red Sea (Descriptio Animatium, etc.), published posthumously in 1775, is one of the most accurate of faunal lists, and one which shows a fine feeling for taxonomic distinctions, scarcely traceable in any previous author. George Wilhelm Steller, naturalist of Bering's expedition, gathered, amid incredible

hardships, the first knowledge of the fishes of Alaska and Siberia; his notes being printed after his tragic death, by Pallas and Kracheninnikow. Petrus Simon Pallas gives the account of his travels in the North Pacific in his most valuable volumes, Zoographia Russo-Asiatica. S. T. Gmelin and Güldenstadt, like Steller, crossed Siberia, recording its animals. Johann David Schöpf, a Hessian Surgeon stationed at Long Island in the Revolutionary War, gave an excellent account of the fishes about New York.

Still other naturalists accompanied navigators around the globe, collecting specimens and information as opportunity offered. John Reinhold Forster and Solander sailed with Captain Cook. Commerson accompanied Bougainville and furnished nearly all the original material used by Lacépède. Other noted travellers of the early days were Sonnerat and Mungo Park.

Other naturalists, scarcely less useful, gave detailed accounts of the fauna of their own native regions. Ablest of these was Anastole Risso, an apothecary of Nice, who published in 1810 the "Ichthyologie de Nice," an excellent work afterwards (1826) expanded by him into a "Histoire Naturelle d'Europe Meridionale."

Contemporary with Risso was a man of opposite character, Constantine Samuel Rafinesque (1784–1842), who wrote at Palermo in 1810 his "Caratteri di Alcuni Nuovi Generi" and "Ittiologia Sciliana." Later he went to America, where he was for a time professor in the Transylvania University in Kentucky. Brilliant, erudite, irresponsible, fantastic, he wrote of the fishes of Sicily and later (Ichthyologia Ohiensis, 1820), of the fishes of the Ohio river, with wide knowledge, keen taxonomic insight and a hopeless disregard of the elementary principles of accuracy. Always eager for novelties, restless and credulous, his writings have been among the most difficult to interpret of any in Ichthyology. Earlier than Risso and Rafinesque, Thomas Pennant wrote of the British fishes, Oscar Fredrik Müller, of the fishes of Denmark, J. E. Gunner, Bishop of Thröndhjem, of fishes of Norway, Duhamel du Monceau, of the fisheries of France, D. J. Cornide of the fishes

of Spain, and Meidinger, of those of Austria. Most of these writers knew little of the Linnæan system, and their records are generally in the vernacular. Most important of this class is the work of Antonio Parra, "Descripcion de Diferentes Piezas de Historia Natural de la Isla de Cuba," published in Havana in 1787. In 1803, Patrick Russell gave a valuable account of "Two hundred fishes collected at Vizagapatam and on the coast of Coromandel." Following this was a work on the fishes of the Ganges, well illustrated, by Francis Buchanan-Hamilton.

Bering Sea and Japan were explored by William Theophilus Tilesius (1775–1835), whose papers are published in the transactions of the early societies of Russia. Stephan Krascheninikov (1786) wrote a history of Russia in Asia, and other geographical writers, as Krüsenstern contributed something to our knowledge of the fishes in regions visited by them.

Other notable names among the early writers are those of Auguste Broussonet of Montpelier, whose work, too soon cut short, showed marked promise. B. A. Euphrasen, Fr. Faber, who wrote of the fishes of Iceland, Everard Home, E. Blyth, who studied the fishes of the Andamans, J. T. Kölreuter, J. Lepechin, John Latham, W. E. Leach, A. G. Desmarest, G. Montague, C. Quensel, H. Strom and M. Vahl.

The compilers who followed Linnæus belonged to a wholly different class. These were men of large learning, methodical ways, sometimes brilliant, sometimes of deep insight, but more often, on the whole, dull, plodding and mechanical.

Earliest of those is Antoine Goüan, whose "Historia Piscium" was published in Paris in 1770. In this work, which is of fair quality, only genera were included, and the three new ones which he introduces into the System (*Lepadogaster*, *Lepidopus* and *Trachypterus*) are still retained with his definition of them.

Johann Friedrich Gmelin published in 1788 a thirteenth edition of the Systema Naturæ of Linnæus, adding to it the discoveries of Forskal, Forster and others who had written since Linnæus' time. This work was useful as bringing that of Linnæus to a later date, but it is not well done, the com-

piler having little knowledge of the animals described and little penetration in matters of Taxonomy. Very similar in value, although more lucid in expression, is the French compilation of the same date (1788), "Tableau Encyclopedique et Méthodique des Trois Règnes de la Nature," by the Abbé J. P. Bonnaterre. Another "Encyclopédie Methodique," of still less merit, was published as a dictionary in Paris, in 1787, by Rene Just Haüy.

In 1792, Johann Julius Walbaum, a German compiler of a little higher rank, gathered together the records of all known species, using the work of Artedi as a basis, and giving binomial names in place of the vernacular terms used by Schöpf, Steller, Pennant and Krascheninnikow.

Far more pretentious and more generally useful as well as containing a large amount of original material is the "Ichthyologia" of Mark Eliezer Bloch, published in Berlin in various parts from 1782 to 1795. It was originally of two parts in German; "Oeconomische Naturgeschichte der Fische Deutschlands" and "Naturgeschichte der Ausländischen Fische." Bloch was a physician, born at Anspach in 1723, and at the age of 56 began to devote himself to Ichthyology. In his great work is contained every species which he had himself seen, every one he could purchase from collections, and every one of which he could find drawings made by others.

That part which relates to the fishes of Germany is admirably done. In the treatment of East Indian and American fishes there is much guess work, and many errors of description and of fact, for which the author was not directly responsible. To learn to interpret the personal equation in the systematic work of other men is one of the most delicate of taxonomic arts.

After the publication of these great folio volumes of plates, Dr. Bloch began a systematic catalogue to include all known species. This was published after his death by his collaborator the philologist, Dr. Johann Gottlob Schneider. This work, "Systema Ichthyologia, M. E. Blochii," contains 1,519 species of fishes, and is the most creditable compilation subsequent to the death of Linnæus.

Even more important than the work of Bloch is that of the Comte de Lacépède, who became, with the progress of the French Revolution, "Citoyen Lacépède," his original full name being Bernard Germain Etienne de la Ville-sur-Illon, Comte de Lacépède. His great work, Histoire Naturelle des Poissons, was published originally in five volumes, in Paris, from 1798 to 1803. It was brought out under great difficulties, his materials being scattered, his country in a constant tumult. For original material he depended chiefly on the collection and sagacious notes of the traveler Commerson. Dr. Gill sums up the strength and weakness of Lacépède's work in these terms:

"A work by an able man and eloquent writer even prone to aid rhetoric by the aid of imagination in absence of desirable facts, but which, because of undue confidence in others, default of comparison of material from want thereof and otherwise, and carelessness generally, is entirely unreliable."

The work of Lacépède had a large influence upon subsequent investigators, especially in France. A large portion of the numerous new genera of Rafinesque were founded on divisions made in the analytical keys of Lacépède.

In 1803 and 1804 Dr. George Shaw published in London his "General Zoology," the fishes forming part of volumes IV and V. This is a poor compilation, the part concerning fishes being largely extracted from Bloch and Lacépède. In 1807, Constant Dumeril published an analytical table of classification of some merit as "Ichthyologie Analytique," and about 1815 H. Ducrotay de Blainville wrote the "Faune Française" and contributed important studies to the taxonomy of sharks.

With Georges Chrétien Leopold Dagobert Cuvier and the "Règne Animal Arrangé apr s son Organization" (1817-1826), we have the beginning of a new era in Ichthyology. This period is characterized by a recognition of the existence of a natural classification based on the principles of Morphology. The Règne Animal is, in the history of Ichthyology, not less important than the Systema Naturæ itself, and from it dates practically our knowledge of families of fishes and the inter-

relations of the groups themselves. The great facts of homology were clearly understood by Cuvier. Their significance as indications of lines of descent was never grasped by him, and this, notwithstanding the fact that Cuvier was almost the first to bring extinct forms into the proper relations with those now living.

Dr. Günther well says that the investigation of anatomy of fishes was continued by Cuvier until he had succeeded in completing so perfect a framework of the system of the whole class that his immediate successors could content themselves with filling up those details for which their master had no leisure. Indefatigable in examining all the external and internal characters of the fishes of a rich collection, he ascertained the natural affinities of the infinite variety of fishes, and accurately defined the divisions, orders, families, and genera of the class, as they appear in the various editions of the "Règne Animal." His industry equalled his genius; he opened connections with almost every accessible part of the globe; not only French travellers and naturalists, but also Germans, Englishmen, Americans, rivalled one another to assist him with collections; and for many years the Museum of the Jardin des Plantes was the center where all ichthyological treasures were deposited. Thus Cuvier brought together a collection the like of which had never been seen before, and which, as it contains all the materials on which his labors were based, must still be considered to be the most important.

The greatest contributions of Cuvier to Ichthyology are contained in the great Histoire Naturelle des Poissons, the joint work of Cuvier and his pupil and successor, Achille Valenciennes. Of this work 22 volumes were published, from 1828 to 1847, containing 4,514 nominal species, the larger number of volumes appearing after the death of Cuvier (1832), the work closing, not quite complete, with the death of Valenciennes in 1848.

This is a most masterly work, still indispensable to the student of fishes. Its descriptions are generally exact, its statements correct, its plates accurate, and its judgements trustworthy. But with all this it is very unequal. Many of the

species are treated very lightly by Cuvier; many of the descriptions of Valenciennes are very mechanical, as though the author had grown weary of the endless process, "a failing commonly observed among zoologists when attention to descriptive details becomes to them a tedious task." As Günther observes, the number of nominal species is almost doubled because the authors neglected to give proper attention to the changes in different species due to age and sex.

After the death of Valenciennes (1848) Dr. Auguste Dumeril (son of Constant Dumeril), began a continuation of this work, publishing two volumes (1865–1870) covering sharks, ganoids, and other fishes not treated by Cuvier and Valenciennes. The death of Dumeril left the great catalogue still incomplete. Dumeril's work is useful and carefully done, but his excessive trust in slight differences has filled his book with nominal species. Thus among the ganoid fishes he recognizes 135 species, the actual number being not far from 40.

We may anticipate the sequence of time by here referring to the remaining attempts at a record of all the fishes in the world. Dr. Albert C. L. G. Günther, a German naturalist resident in London, and long the keeper of the British Museum, published in eight volumes the "Catalogue of the Fishes of the British Museum" from 1859 to 1870. In this monumental work, the one work most essential to all systematic study of fishes, 6,843 species are described and 1,682 doubtful species are mentioned. The book is a tremendous example of patient industry. Its great merits are at once apparent, and those of us engaged in the same line of study may pass by its faults with the same leniency which we may hope that posterity may bestow on ours.

The publication of this work gave a remarkable stimulus to the study of fishes. The number of known species had been raised from 9,000 to about 12,000, and some hundreds of species even accepted by the conservatism of Günther have been erased from the system.

A new edition of this work has been long in contemplation, and in 1898 the first volume of it, covering the Percoid fishes, was published by Dr. George Albert Boulenger. This volume

is one of the most satisfactory in the history of Ichthyology. It is based on ample material. Its accepted species have been subject to thorough criticism, and in its classification every use has been made of the teachings of morphology and especially of Osteology. Its classification is distinctly modern, and with the writings of the contemporary ichthyologists of Europe and America, it is fully representative of the scientific era ushered in by the researches of Darwin. The chief criticism which one may apply to this work concerns most of the publications of the British Museum. It is the frequent assumption that those species not found in the greatest museum of the world do not really exist at all. There are still many forms of life, very many, outside this series gathered in any or all collections.

We may now turn from the universal catalogues to the work on special groups, on local faunas, or on particular branches of the subject of Ichthyology. These lines of study were made possible by the work of Cuvier and Valenciennes, and especially by that of Dr. Günther.

Before taking up the students of faunal groups, we may, out of chronological order, consider the researches of three great taxonomists, who have greatly contributed to the modern system of the classification of fishes.

Louis Agassiz (born in Western Switzerland in 1807, died at Cambridge, Massachusetts, in 1873), was a man of wonderful insight in zoological matters, and possessed a varied range of scientific information scarcely excelled in any age—intellectually a lineal descendant of Aristotle. His first work on fishes was the large folio on the fishes collected by Jean Baptiste Spix in Brazil, published at Munich, in 1827. After his establishment in America in 1846, at which time he became a professor in Harvard University, Agassiz published a number of illuminating papers on the fresh-water fishes of North America. He was the first to recognize the necessity of the modern idea of genera among fishes, and almost all of the groups so designated by him are retained by later writers. He was also the first to investigate the structure of the singular viviparous surf-fishes of California, the names Embiotoca and Holconoti applied to these fishes being chosen by him.

His earlier work, "Recherches sur les Poissons des Eaux Douces," published in Europe, gave a great impetus to our knowledge of the anatomy and especially of the embryology of the fresh-water fishes. Most important of all his zoological publications was the "Recherches sur les Poissons Fossiles," published at Neufchatel from 1833 to 1843. This work laid the foundation of the systematic study of the extinct groups of fishes. The relations of sharks were first appreciated by Agassiz, and the first segregation of the ganoids was due to him. Although he included in this group many forms not truly related either to the ganoids or even to the extinct Arthrognaths, yet the definition of this order marked a great step in advance.

The great, genial, hopeful personality of Agassiz, and his remarkable skill as a teacher, made him the "best friend that ever student had," and gave him a large following as a teacher. Among his pupils in Ichthyology were Charles Girard, Frederick Ward Putnam, Alexander Agassiz, Samuel Garman, Samuel H. Scudder, and the present writer.

Johannes Müller (1808–1858), of Berlin, was one of the greatest of comparative anatomists. In his revision of Cuviers' system of classification he corrected many errors in grouping, and laid foundations which later writers have not altered or removed. Especially important is his classical work, "Ueber den Bau and die Grenzen der Ganoiden." In this he showed the real fundamental characters of that group of Archaic fishes, and took from it the most heterogenous of the elments left in it by Agassiz. To Müller we also owe the first proper definition of the Leptocardii and the Cyclostomi, and, in association with Dr. J. Henle, Müller has given us one of the best general accounts of the sharks ("Systematische Beschriebungen der Plagiostomen"). To Müller we owe an accession of knowledge in regard to the duct of the air-bladder, and the groups called *Dipneusti* (*Dipnoi*), *Pharyngognathi*, and *Anacanthini* were first defined by him, although now usually restricted within narrower limits than those assigned by him.

In his work on the Devonian fishes, the great British com-

parative anatomist, Thomas Henry Huxley, first distinguished the group of Crossopterygians, and separated it from the Ganoids and Dipnoans.

Theodore Nicholas Gill is the keenest interpreter of taxonomic facts yet known in the history of Ichthyology. He is the author of an immense number of papers, the first bearing date of 1858, touching almost every group and almost every phase of relation among fishes. His numerous suggestions as to classification have been usually accepted in time by other authors, and no one has had a clearer perception than he of the necessity of orderly methods in nomenclature. Among the orders first defined by Gill are the Eventognathi, the Haplomi, the Xenomi, and the group called Teleocephali, which included all the bony fishes except those which showed peculiar eccentricities or modifications. Dr. Gill's greatest excellence has been shown as a scientific critic. Incisive, candid and friendly, there is scarcely a scientific man in America who is not directly indebted to him for critical aid of the highest importance. The present writer cannot too strongly express his own obligations to this great teacher, his master in fish taxonomy, as Agassiz was in fish ecology. Dr. Gill's work is not centered in any single great treatise, but is diffused through a very large number of brief papers and catalogues, those from 1861 to 1865 mostly published by the Academy of Natural Sciences in Philadelphia, those of recent date by the United States National Museum. For many years Dr. Gill has been identified with the work of the Smithsonian Institution at Washington.

Closely associated with Dr. Gill was Dr. Edward Drinker Cope, of Philadelphia, a tireless worker in almost every field of Zoology, and a large contributor to the broader fields of ichthyological taxonomy as well as to various branches of descriptive Zoology. Cope was one of the first to insist on the close relation of the true Ganoids with the Teleost fishes, the nearest related group of which he defined as *Isospondyli*. In breadth of vision and keenness of insight, Cope ranked with the first of taxonomic writers. Always bold and original, he was not at all times accurate in details, and to the final result

in classification his contribution has been less than that of Dr. Gill. Professor Cope also wrote largely on American fresh-water fishes, a large percentage of the *Cyprinidæ* and *Percidæ* of the Eastern United States having been discovered by him, as well as much of the Rocky Mountain fauna. In later years his attention was absorbed by the fossil forms, and most of the species of the cretaceous rocks and the eocene shales of Wyoming were made known through his ceaseless activity.

The enumeration of other workers in the great field of Ichthyology must assume something of the form of a catalogue. Part of the impulse received from the great works of Cuvier and Valenciennes and of Günther was spent in connection with voyages of travel. In 1824, Quoy and Gaimard published in Paris the great folio work on the fishes collected by the corvettes *l'Uranie* and *la Physicienne* in Freycinet's voyage around the world. In 1834, the same authors published the fishes collected in Dumont D'Urville's voyage of the *Astrolabe*. In 1826, Lesson published the fishes of the voyage of the *Coquille*. These three great works lie at the foundation of our knowledge of the fishes of Polynesia. In 1839, Eydoux and Gervais published the fishes of the voyage of *La Favorite*.

In 1853, also in Paris, Hombron and Jacquinot gave an account of the fishes taken in Dumont D'Urville's expedition toward the South Pole. In England, Sir John Richardson, a wise and careful naturalist, wrote of the fishes collected by the *Sulphur* (1845), the *Erebus* and *Terror* (1846), and the *Herald*. Lay and Bennett recorded the species taken by Beechey's Voyage of the *Blossom*. More important than any of these is the account of the species taken by Charles Darwin on the voyage of the *Beagle*, prepared by the conscientious hand of Rev. Leonard Jenyns. Still more important and far ranging is the voyage of the *Challenger*, including the first important work in the deep seas, the stately volume and parts of other volumes on fishes being the work of Dr. Günther. Other deep-sea work of equal importance has been accomplished in the Altantic and the Pacific by the U. S. Fish Commission steamer *Albatross*. Its results in Central America, Alaska,

Japan, as well as off both coasts of the United States, have been made known in different memoirs by Goode and Bean, Garman, Gilbert, Gill, Jordan, Cramer and others. The deep-sea fish collections of the *Fish Hawk* and the *Blake* have been studied by Goode and Bean and Garman.

The deep-sea work of other countries may be briefly noticed. The French vessels, *Travailleur* and *Talisman*, have made collections chiefly in the Mediterranean and along the coast of Africa, the results having been made known by Leon Vaillant. The *Hirondelle* about the Azores and elsewhere has furnished material for Professor Robert Collett of the University of Christiania. Dr. Decio Vincignerra of Rome has reported on the collections of the *Violante*, a vessel belonging to the Prince of Monaco. Dr. A. Alcock, of Calcutta, has had charge of the most valuable deep-sea work of the *Investigator* in the Indian seas. Dr. James Douglas Ogilby and Dr. Edgar R. Waite, of Sidney, have described the collections of the *Thetis*, on the shores of New South Wales.

From Austria the voyage of the frigate *Novara* has yielded large material which has been described by Dr. Rudolph Kner. The cream of many voyages of many Danish vessels has been gathered in the "Spolia Atlantica" and other truly classical papers of Christian Fredrik Lütken, of the University of Copenhagen, one of the great naturalists of our times.

F. H. von Kittlitz has written on the fishes seen by him in the northern Pacific, and earlier and more important we may mention the many ichthyological notes found in the travel records of Alexander von Humboldt in Mexico and South America.

The local faunal work in various nations has been very extensive. In Great Britain we may note Parnell's "Natural History of the Fishes of the Firth of Forth," published in Edinburgh in 1838; William Yarrell's History of British Fishes (1859); the earlier histories of British fishes by Edward Donovan and by William Turton, and the works of J. Couch (1862), and Dr. Francis Day (1888), possessing similar titles. The work of Day, with its excellent plates, will long be the standard account of the relatively scant fish fauna of the

British Islands. H. G. Seelye has also a useful Synopsis of the Fresh-water Fishes of Europe.

We may here notice without praise the extensive work of William Swainson (1839). W. Thompson has written of the fishes of Ireland, and Rev. Richard T. Lowe and J. Y. Johnson have done most excellent work on the fishes of Madeira. F. McCoy, better known for work on fossil fishes, may be mentioned here.

The fish fauna of Scandinavia has been described more or less fully by Kröyer (1840), Nilsson (1855), Fries and Ekström (1836), Collett, Lilljeborg and F. A. Smitt, besides special papers by other writers, notably Reinhardt, L. Esmarck, Japetus Steenstrup, Lütken, and A. W. Malm. Reinhardt, Kröyer, Lütken, and A. J. Malmgren have written of the Arctic fishes of Greenland and Spitzbergen.

In Russia Nordmann has described the fishes of the Black Sea ("Ichthyologie Pontique," Paris, 1840), and Eichwald those of the Caspian. More recently, S. Herzenstein, Warpachowsky, K. Kessler, B. N. Dybowsky, Kamensky, and others have written of the rich fauna of Siberia, the Caucasus and the scarcely known sea of Ochotsk. Stephen Basilevsky has written rather unskillfully of the fishes of Northern China. A. Kowalevsky has contributed very much to our knowledge of anatomy.

In Germany and Austria the chief local works have been those of Heckel and Kner on the fresh-water fishes of Austria (1858), and C. Th. von Siebold on the fresh-water fishes of Central Europe (1863). German ichthyologists have usually extended their view to foreign regions where their characteristic thoroughness and accuracy has made their work illuminating. The two memoirs of Edouard Rüppell on the fishes of the Red Sea and neighboring parts of Africa, "Atlas zu der Reise im Nördlichen Afrika," 1828, and "Neue Wirbelthiere," 1837, rank with the very best of descriptive work. Günther's finely illustrated "Fische der Südsee," published in Hamburg, may be regarded as German work. Other papers are those of Dr. Wilhelm Peters on Asiatic Fishes, the most important being on the fishes of Mozambique. J. J.

Heckel, Rudolph Kner and Franz Steindachner, successively curators of the Museum at Vienna, have written largely on fishes. The papers of Steindachner cover almost every part of the earth and are absolutely essential to any serious systematic study of fishes. No naturalist of any land has surpassed Steindachner in industry or accuracy, and his work has the advantage of the best illustrations of fishes made by any artist, the noted Edouard Konopicky. Other German writers are J. J. Kaup, who has worked in numerous fields, but as a whole with little skill; Dr. S. B. Klunzinger, who has given excellent accounts of the fishes of the Red Sea, and Dr. Franz Hilgendorf, of the University of Berlin, whose papers on the fishes of Japan and other regions have shown a high grade of taxonomic insight. Other writers of earlier date are Johann Marcusen, who studied the Mormyri; W. von Repp, who wrote on the fishes of the lake of Constance, and J. F. Brandt.

In Italy, Charles Lucien Bonaparte, Prince of Canino, has published an elaborate "Fauna Italica" (1838) and in numerous minor papers has taken a large part in the development of Ichthyology. Many of the accepted names of the large groups (as *Elasmobranchii*, *Heterosomata*, etc.) were first suggested by Bonaparte. The work of Rafinesque has been already noticed. O. G. Costa published (about 1850) a Fauna of Naples. In recent times G. Canestrini, Decio Vincignerra, Enrico Hillyer Giglioli, Luigi Doderlein and others have contributed largely to our knowledge of Italian fishes, while Carlo F. Emery, F. de Filippi, Luigi Facciola and others have studied the larval growth of different species. Camillo Ranzani, G. G. Bionconi, G. D. Nardo, and others have contributed to different fields of Ichthyology.

Nicolas Apostolides and, still later, Horace A. Hoffman and the present writer have written of the fishes of Greece.

In France, the fresh-water fishes are the subject of an important work by Emile Blanchard (1866) and Emile Moreau has given us a convenient fauna of France. Leon Vaillant has written on various groups of fishes, his monograph of the American darters (*Etheostominæ*) being a masterpiece so far

as the results of the study of relatively scanty material would permit. The "Mission Scientifique au Mexique," by Vaillant and F. Bocourt, is one of the most valuable contributions to our knowledge of the fishes of that region. Dr. H. E. Sauvage, of Boulogne-sur-Mer, has also written largely on the fishes of Asia, Africa and other regions.

Important among these are the "Poissons de Madagascar," and a monograph of the Sticklebacks. Alexander Thominot and Jacques Pellegrin have also written, in the Museum of the Jardin des Plantes, on different groups of fishes. Earlier writers were Alphonse Guichenot, L. Brissot de Barneville, H. Hollard, an able anatomist, and Bibron.

In Spain and Portugal, the chief work of local authors is that of J. V. B. de Bocage and F. de Brito Capello on the fishes of Portugal. So far as Spain is concerned, the chief memoir is Steindachner's account of his travels in Spain and Portugal. The principal studies of the Balkan region have also been made by Steindachner.

In Holland the chief great works have been those of Schlegel and Pieter van Bleeker. Professor Schlegel, of the University of Leyden, described the fishes collected about Nagasaki by Ph. Fr. de Siebold and Bürger. His work forms a large folio illustrated by colored plates. The fauna Japonica, Poissons, was published in Leyden from 1844 to 1850. Schlegel's work in every field is characterized by scrupulous care and healthful conservatism, and the fauna Japonica is a most useful monument to his rare powers of discrimination.

Pieter von Bleeker (1819–1878), a surgeon in the Dutch East Indies, is the most voluminous writer in Ichthyology. He began his work in Java without previous training and in a very rich field where almost everything was new. With many mistakes at first he rose to the front by sheer force of industry and patience, and his later work, while showing much of the "personal equation," is still thoroughly admirable. At his death he was engaged in the publication of a magnificent folio work, "Atlas Ichthyologique des Indes Orientales Neerlandaises," illustrated by colored plates. This work remains about two-thirds completed. The writings of Dr. Bleeker con-

stitute the chief source of our knowledge of the fauna of the East Indies.

Dr. Van Lidth de Jeude, of the University of Leyden, is the author of a few descriptive papers on fishes.

To Belgium we may assign part at least of the work of the eminent Belgian naturalist, George Albert Boulenger, now long connected with the British Museum. His various valuable papers on the fishes of the Congo are published under the auspices of the "Congo Free State," itself largely a creation of the government of Belgium. To Belgium also we may ascribe the work of Louis Dollo on the morphology of fishes, and on the deep-sea fishes obtained by the "Expedition Antarctique Belge."

The fish fauna of Cuba has been the life-long study of Dr. Felipe Poey y Aloy (1799–1891) a pupil of Cuvier, for a half century or more the honored professor of zoology in the University of Havana. Of his many useful papers, the most extensive are his "Memorias sobre la Historia Natural de la Isla de Cuba," followed by a "Repertorio" and an "Enumeratio" on the same subject. Poey devoted himself solely to the rich fish fauna of his native island, in which region he was justly recognized as a ripe scholar and a broad-minded gentleman. A favorite expression of his was, "Comme naturaliste, je ne suis pas espagnol: je suis cosmopolite." Before Poey Guichenot of Paris had written on the fishes collected in Cuba by Ramon de la Sagra. His account was published in Sagra's Historia de Cuba, and later Philip H. Gosse (1810–1888) wrote on the fishes of Jamaica. Much earlier, Robert Herrmann Schomburgk (1804–1865) wrote on the fishes of British Guiana. Other papers on the Caribbean Fishes were contributed by Johannes Müller and F. H. Troschel, and by Richard Hill and J. Hancock.

Besides the work in South America of Marcgrave, Agassiz Reinhardt, Lütkin, Steindachner, Jenyns, Boulenger, and others already named, we may note the local studies of Dr. Carlos Berg in Argentina, Dr. R. A. Philippi in Chile, and special records of Humboldt, Garman, J. F. Abbott, and others in recent times. Carl H. Eigenmann and also Jordan and Eigen-

mann have studied the great collections made in Brazil by Agassiz. Steindachner has described the collection of Johann Natterer and Gilbert those made by Dr. John C. Branner. The most recent extensive studies of the myriads of Brazilian river fishes are those of Dr. Eigenmann. Earlier than any of these Francis de Castelnau (1855), described many Brazilian fishes and afterwards numerous fishes of Australia. Guichenot, of Paris, contributed a chapter on fishes to Claude Gay's history of Chile, and J. J. von Tschudi, of St. Gallen, published an elaborate but uncritical "Fauna Peruana" with colored plates of Peruvian fishes.

In New Zealand, F. W. Hutton and J. Hector have published a valuable work on the fishes of New Zealand, to which Dr. Gill added valuable critical notes in a study of "Antipodal Faunas." Later writers have given us a good knowledge of the fishes of Australia. Notable among them are W. Macleay, James Douglas Ogilby, and Edgar R. Waite. Clarke has also written on "Fishes of New Zealand."

The most valuable work on the fishes of Hindustan is the elaborate treatise on the "Fishes of India," by Surgeon Francis Day. In this all the species are figured, the groups being arranged as in Günther's catalogue, a sequence which few non-British naturalists seem inclined to follow. Cantor's Malayan Fishes is a Memoir of high merit, as is also McClelland's work on the fishes of the Ganges, and we may here refer to Andrew Smith's papers on the fishes of the Cape of Good Hope, and to R. I. Playfair and A. Günther's Fishes of Zanzibar. T. C. Jerdon, John Edward Gray, E. Tyrwhitt Bennett, J. Bennett, and others have also written on the fishes of India.

In Japan, following the scattering papers of Thunberg, Tilesius and Houttuyn, and the monumental work of Schlegel, numerous species have been recorded by James Carson Brevoort, Günther, Gill, Edouard Nyström, Hilgendörf, and others. About 1884, Steindachner and Döderlein published the valuable "Fische Japans," based on the collections made about Tokyo by Dr. Döderlein. In 1881, Motokichi Namiye, then, as now, Assistant Curator in the Imperial University, published the first list of Japanese fishes by a native author.

In 1900, Dr. Chiyomatsu Ishikawa, in a paper on the fishes of Lake Biwa, was the first Japanese author to venture to make a new species of fish (*Pseudogobio zezera*). This reticence was due not wholly to lack of self-confidence, but rather to the scattered condition of the literature of Japanese Ichthyology. For this reason no Japanese author has ever felt sure that any given undetermined species was really new. Other Japanese Ichthyologists of promise are Dr. Kumakichi Kishinouye, Dr. Shinnosuke Matsubara and Keinosuke Otaki, and we may look for others among the pupils of Dr. Kakichi Mitsukuri, the distinguished Professor of Zoology in the Imperial University.

The most recent, as well as the most extensive, studies of the fishes of Japan were made in 1900 by the present writer and his associate, John Otterbein Snyder.

The scanty pre-Cuvieran work on the fishes of North America has already been noticed. Contemporary with the early work of Cuvier is the worthy attempt of Professor Samuel Latham Mitchell (1764–1831) to record in systematic fashion the fishes of New York. Soon after followed the admirable work of Charles Alexander Le Sueur (1780–1840), artist and naturalist, who was the first to study the fishes of the Great Lakes and the basin of Ohio. Le Sueur's engraving of fishes in the early publications of the Academy of Natural Sciences in Philadelphia, are still among the most satisfactory representations of the species to which they refer. Constantine Samuel Rafinesque (1784–1842), the third of this remarkable but very dissimilar trio, published numerous papers descriptive of the species he had seen or heard of in his various botanical rambles. This culminated in his elaborate but untrustworthy Ichthyologia Ohiensis. The fishes of Ohio received later a far more conscientious, though less brilliant, treatment at the hands of Dr. Jared Potter Kirtland (1793–1877), an eminent physician of Cleveland, Ohio. In 1842, the amiable and scholarly James Ellsworth Dekay (1799–1851), published his detailed report on the New York fauna, and a little earlier (1836), in the Fauna Boreali-Americana Sir John Richardson (1787–1865) gave a most valuable and accurate account of

the fishes of the Great Lakes and Canada. Almost simultaneously, Rev. Zadock Thompson (1796-1856) gave a catalogue of the fishes of Vermont, and David Humphreys Storer (1804-1891) began his work on the fishes of Massachusetts, finally expanded into a "Synopsis of the Fishes of North America" (1846) and a "History of the Fishes of Massachusetts" (1867). Dr. John Edwards Holbrook (1794-1871), of Charleston, published (1860) his invaluable record of the fishes of South Carolina, the promise of still more important work, which was destroyed by the outbreak of the Civil War. The Monograph on Lake Superior (1850), and other publications of Louis Agassiz (1807-1873), have been already noticed. One of the first of Agassiz's students was Charles Girard (1822-1895), who came with him from Switzerland, and in association with Spencer Fullerton Baird (1823-1887) described the fishes from the United States Pacific Railway Surveys (1858), and the United States and Mexican Boundary Surveys (1859). Professor Baird, primarily an ornithologist, became occupied with executive matters, leaving Girard to finish these studies of the fishes. A large part of the work on fishes published by the United States National Museum and the United States Fish Commission has been made possible through the direct help and inspiration of Professor Baird. Among those engaged in this work James M. Milner, Hugh M. Smith, Marshall Macdonald may be noted.

Most eminent, however, among the students and assistants of Professor Baird was his successor, George Brown Goode (1851-1899), one of the most accomplished of American naturalists, whose greatest work, Oceanic Ichthyology, published in collaboration with his associate of many years, Dr. Tarleton Hoffman Bean, was barely finished at the time of his death. The work of Theodore Nicholas Gill and Edward Drinker Cope has been already noticed.

Other faunal writers of more or less prominence were William Dandridge Peck (1763-1822) in New Hampshire, George Suckley (1830-1869) in Oregon, James William Milner (1841-1880) in the Great Lake Region, Samuel Stehman Holdeman (1812-1880) in Pennsylvania, William O. Ayres (1817-1891)

in Connecticut and California, Dr. John G. Cooper, Dr. William P. Gibbons, and William N. Lockington in California. Philo Romayne Hoy (1816–1893), studied the fishes of Wisconsin, Charles Conrad Abbott those of New Jersey, and Silas Stearns (1859–1888) those of Florida, and Stephen Alfred Forbes those of Illinois.

Samuel Garman, at Harvard University, a student of Agassiz, is the author of numerous valuable papers, the most notable being on the sharks and on the deep-sea collections of the *Albatross* in the Galapagos region, the last illustrated by most excellent plates.

The present writer began a systematic Catalogue of the Fishes of North America in 1875, in association with his gifted friend, Herbert Edson Copeland (1849–1876), whose sudden death, after a few excellent pieces of work, cut short the undertaking. Later, Charles Henry Gilbert (1860–), a student of Professor Copeland, took up the work, and in 1883 a "Synopsis of the Fishes of North America" was completed by Jordan and Gilbert. Dr. Gilbert has since been engaged in studies of the fishes of Panama, Alaska, and other regions, and the second and enlarged edition of the Synopsis was completed in 1898, as the "Fishes of North and Middle America," in collaboration with another of the writer's students, Dr. Barton Warren Evermann. A Monographic Review of the Fishes of Puerto Rico was later (1900) completed by Dr. Evermann, together with numerous minor works. Other naturalists whom the writer may be proud to claim as students are Charles Leslie McKay (1854–1883), drowned in Bristol Bay, Alaska, while engaged in explorations, and Charles Henry Bollman, stricken with fever in the Okefenokee Swamps in Georgia. Still others were Dr. Carl H. Eigenmann, the indefatigable investigator of Brazilian fishes and of the blind fishes of the caves; Dr. Oliver Peebles Jenkins, first explorer of the fishes of Hawaii; Dr. Alembert Winthrop Brayton, explorer of the streams of the Great Smoky Mountains; Dr. Seth Eugene Meek, explorer of Mexico; John Otterbein Snyder, explorer of Mexico, Japan, and Hawaii; Edwin Chapin Starks, explorer of Puget Sound and Panama and investigator of fish osteology. Still other natu-

ralists of the coming generation, students of the present writer and of his lifelong associate, Professor Gilbert, have contributed in various degrees to the present fabric of American Ichthyology. Among them are Mrs. Rosa Smith Eigenmann, Dr. Joseph Swain, Wilbur Wilson Thoburn, Frank Cramer, Alvin Seale, Albert Jefferson Woolman, Philip H. Kirsch, Cloudsley Rutter, Robert Edward Snodgrass, James Francis Abbott, Arthur S. Greeley, Edmund Heller, Henry Weed Fowler, and Richard Crittendon McGregor.

Other facts and conclusions of importance have been contributed by various persons with whom Ichthyology has been an incident rather than a matter of central importance.

As students of the extinct fishes, following the monumental work of Louis Agassiz, some of the notable names are those of Pander, Asmuss, Heckel, Hugh Miller, and R. H. Traquair. An indispensable "Handbuch der palæontologie" is that of Karl A. Zittel (1890), in which the knowledge of fossil fish is brought up to a recent date. The most valuable general work is the "Catalogue of the Fossil Fishes in the British Museum" in four volumes, by Dr. Arthur Smith Woodward, a most worthy companion of Günther's Catalogue of the living fishes, and still more modern in the taxonomy and views of relationships. Important contributions are those of Huxley, F. McCoy, Van den Marck, de Koninck, Davis, Nicholson, Charlesworth, Sir Philip Egerton, Rictet, Kner, von Meyer, Hasse, Thiolliere, Jaekel, Rohon, Sauvage, Stolicza, Lawley, Molin, Gibbes, Probst, Karpinsky, Kipryanoff, and many others.

In America Dr. John Strong Newberry has studied the fossil fishes of Ohio. Professor Edward W. Claypole has worked largely in the same region; Edward Drinker Cope and Dr. Joseph Leidy on the Eocene and Cretaceous Fishes of the Rocky Mountains. Numerous recent papers of great value have been published by Dr. Bashford Dean, of Columbia University, and Dr. Charles R. Eastman, of Harvard. Other important records are due to Orestes St. John, A. H. Worthen, Charles D. Walcott, and the Redfields, father and son.

Still more difficult of enumeration is the long list of those who have studied the anatomy of fishes, usually in connection with

the comparative anatomy or development of other animals. Pre-eminent among these are Karl Ernst von Baer, Cuvier, Geoffrey St. Hilaire, Louis Agassiz, Johannes Müller, Carl Vogt, Carl Gegenbaur Meckel, William Kitchen Parker, Francis M. Balfour, Thomas Henry Huxley, H. Rathke, Richard Owen, Kowalevsky, H. Stannius, Joseph Hyrtl, Gill, Boulenger and Bashford Dean. Other names of high authority are those of Wilhelm His, Kölliker, Bakker, Rosenthal, Göttsche, Mikluche, Macleay, Weber, Hasse, Retzius, Owsjannikow, H. Müller, Stieda, Marcusen, and Ryder.

Besides all this there has risen, especially in the United States, Great Britain, Norway and Canada and Australia, a vast literature of Commercial Fisheries, Fish Culture and Angling, the chief workers in which fields we may not here enumerate even by name.

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Morphology of Insect Galls. By Melville T. Cook, Greencastle, Ind.

Plankton Pulses. By Charles A. Kofoid, University of California, Berkeley, Cal.

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SECTION G.

BOTANY.

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ADDRESS

BY

B. T. GALLOWAY,

VICE-PRESIDENT AND CHAIRMAN OF SECTION G FOR 1901.

APPLIED BOTANY, RETROSPECTIVE AND PROSPECTIVE.

It has been the general practice in past years for the retiring Vice-President of this Section to give a summary of the results accomplished in research work, and to point out the lines along which there appears promise of further advancement. The facts set forth in these addresses and the opportunities pointed out in them, have proved of great advantage to all, especially the younger men, who draw their inspiration from what has been accomplished in the past and what the future holds forth. In choosing my subject I have deviated somewhat from the usual practice heretofore followed, not because I have anything particularly new to say or any particularly startling facts to disclose, but rather for the reason that it seems desirable at this time to emphasize some of the things that appeal to us as possibly having a marked influence on the future development of botanical work. To one who is necessarily thrown in contact with the somewhat hurly-burly affairs of life, the old meaning of botanical work is gradually giving way to something else—something that reaches out into practical affairs and pushes its way into paths where, a few years ago, the botanist would have feared to tread.

Now the question arises, is botanical science to suffer by this movement, or is it, after the first preliminary efforts, to emerge rehabilitated, stronger and more vital than ever before? I have neither fear nor doubt as to the outcome, and

believe that the spirit which has made us commercially a leader of nations will enable us to build up a science which neither time nor change can seriously affect. It hardly needs any extended statement to call to mind the rapid changes which have taken place in botanical work and botanical thought during the past twenty years, yet a critical study of these changes is, to me, one of the most hopeful signs that our progress has constantly been in the direction of a stronger place in the world's usefulness and a higher plane of scientific thought. Twenty years ago the botany taught in our universities and colleges was of such a nature as to meet the general requirements of the time. It broadened out rapidly during the last ten years of this period, but it was still limited in large part to systematic studies, with some few attempts here and there to enter the field of morphology, physiology, and the kindred branches. Perhaps no one thing has given a greater stimulus to applied botany than the organization of the various State Experiment Stations, under what is known as the Hatch Act, which became a law in 1886 and went into active operation a year later. Under the broad authority given in this Act, establishing a Station in each State and Territory, opportunities were afforded for advanced studies of both plants and animals in their bearing on agricultural development, and as a result there was an extraordinary demand for men, which, even yet, it is impossible to meet.

Coincident with the establishment of the Experiment Stations came a broadening of the work of the National Department of Agriculture, thus creating the need for still more men trained in certain lines. At this time the era of specialization was scarcely upon us, but such was the demand for men and work that the stimulus to those engaged in special lines was great.

Of course this country was not alone in the movement which has just been described, for in Europe and particularly in France, there was experienced the same need for help in applied lines, and as a result extraordinary efforts were put forth by those in charge of chairs in the various institutions

of learning to meet these demands. The happenings such as we are describing are met with frequently in the progress of the world, and are really the culmination of more or less subjective thought, which, when the proper moment arrives, breaks into force and makes itself felt in an objective way. It is found, therefore, that while this work was making rapid strides, the demand was so great for immediate practical results that sufficient attention was not always given to that accuracy and precision of conclusion that the world's best thought demands. There was a proneness, in other words, to sacrifice accuracy to utility. Helmholtz, long ago, sounded a warning on this subject when he said that "Whoever in the pursuit of science seeks after immediate practical utility may generally rest assured that he will seek in vain." On the other hand, there is a class of investigators, and their numbers are considerable, whose work, for the most part, is largely ahead of the practical side. Possibly, taking all of the work that has been done in this country, the need is not so much for more research, but for the practical application of the researches already made to the everyday affairs of life. In some branches this, of course, has not been the case, as is evidenced by what has been accomplished in a number of important fields during the past fifteen years.

Of the different branches of botanical science that have been applied to the betterment of man, physiology and pathology stand pre-eminently to the front. We cannot lay any great claim to much in the way of studies in the pure science of physiology, but the practical application of these studies to the affairs of life has been considerable.

In passing, I may be pardoned for emphasizing somewhat in detail a fact that seems to be little appreciated, and that is the great value and usefulness of the individual or organization that can bring to the attention of the people the results of scientific work in such a way that mankind as a whole is bettered, and the struggle for life is made less a burden. What value to the world is a scientific discovery unless it is clothed by some genius with a force that will bring its usefulness home to thousands, where before it would have been

known to but a few of the elect? While willing to admit that America, for very good reasons, has not as yet been able to take front rank in the way of original discoveries, no one will deny the fact that our country has quickly turned to practical account discoveries of all kinds where there was promise of practical results. So that while in physiology, laboratory investigations have been pushed with vigor abroad, our efforts have been in the past mainly in the direction of broad field work, which has added materially to the wealth and power of the country. This is particularly the case with the work on legumes and the application of laboratory discoveries to the problems connected with nitrogen supply and the rotation of crops. The extended work of Laws and Gilbert and other experimenters, has done much to emphasize the value of the broad application of laboratory research in this field. It sometimes happens in work of this kind that its application is of such a special nature as to preclude a proper appreciation of its value in a general way. Such, for example, is the work of Lōew, who three years ago undertook a very special problem having to do with the handling of tobacco, and which, in two years, was practically finished, but so changed the aspect of the work that it opened great possibilities in building up an important industry and adding wealth to the country as well. The keen competition in tobacco growing, and the fact that the finest grades were, in large part, imported, made it very desirable and important that all available information in regard to the crop be secured. The chief problem upon which light was needed had to do with the fermentation of the leaf. Prior to Lōew's work it was generally held that fermentation was, in large part, due to bacteria, and that the difference in the aromas of tobacco might, to a certain degree, be controlled through the action of these organisms. Lōew's work showed that the fermentation of tobacco was due to enzyms. The enzyms causing the fermentation were isolated, and methods for controlling them were pointed out. As a result of this work improved methods of handling the crop have been developed and new industries established. Such, for example, is the Sumatra tobacco industry developed in

Connecticut, which owes its incentive to the advanced work of Löew, and which bids fair to add a great deal to the material wealth of the country.

Plant breeding is another branch of applied work closely related to physiology, which has made rapid advances during the past few years. It is true that plant breeding leads off into horticultural and other fields, but the advances that have been made in this field in recent years have had their inception largely in botanical studies. The work, as a whole, has had for its object the advancement of industrial pursuits, and has aided materially in adding to the wealth and progress of the country. It is true that in some cases applied work in this line has been pushed in advance of scientific research, but this has led to no serious results, for notwithstanding a lack of knowledge as to the full scientific significance of the various operations performed, the results have in most cases shown far-reaching intuitive knowledge on the part of those who have actually been engaged upon the various problems. What has been accomplished by Bailey, Webber, Waugh, Burbank, Hays, and others has shown great possibilities, and the improvements made in many crops will, no doubt, in time, prove of more value than even the present seems to indicate.

In no branch of botanical science have the advances in applied work been more pronounced than in pathology. Twenty years' ago plant pathology was practically unknown in this country. Little or no attempt had been made toward systematic work in this field, and what had been accomplished was largely in the direction of applying information secured as a result of investigations abroad. The first attempts in the study of pathological problems were naturally confined to questions having to do with parasites. The effects of parasitic enemies of plants were pronounced, and gave opportunity for the most ready investigation. In looking back, therefore, on the early development of the work, it is not strange to find that investigations for the most part were in the direction of economic mycology, for it was largely a study of parasitic fungi in their relation to plant diseases. The

important problems connected with the relation of the fungus to the host and host to fungus were, for the most part, overlooked. Pathology, therefore, had its inception largely in mycological investigations, which later developed into a study of the host itself. This naturally led into the field of plant physiology, and developed slowly the important work of investigating plant environment and its relation to pathological phenomena. It was early seen that no sharp line of distinction could be drawn between any of these various branches, and for this reason it became important to push the investigations along several different lines. To the early workers in this field is due the credit of laying the foundation which paved the way for a full understanding of the broad problems elucidated later, and as a result the science itself has been established on a firm basis.

It is the practical application of this science, however, that has attracted such widespread attention everywhere, especially the work which has been done in this country and in France. Prior to 1885, very little was known in regard to the treatment of plant diseases. The discovery of the efficacy of certain compounds in the treatment of crop diseases about this time led to a rapid awakening of the importance of the subject, and for the next few years there was a phenomenal advancement in the field treatment of plant maladies. Improvements in laboratory methods also did much to stimulate advanced work, and made possible lines of research which were not practicable before the discovery of such methods. What has been accomplished in this field alone has done much to encourage applied work and to show the importance of such work as an aid to the advancement of pure science.

It has become the practice of late to ignore the important part that systematic botany has played in making known the practical value of plants to the human race. In the rage for special problems, the fact is often overlooked that many of them owe their inception to prior efforts in taxonomic lines. It is hardly necessary or essential to go into details upon the bearing of systematic botany to applied work; but in passing,

attention should be called to the great benefit that has come to the country as a whole through the important work on grasses, forestry, and medicine. Some of the earliest work in economic lines in this country was based primarily on the systematic study of grasses, the object being to determine their agricultural value. The early investigations of Vasey did much to call attention to the value of applied botany, and there has been developed from this work very important and far-reaching lines of research, such as are now being carried on by the U. S. Department of Agriculture and many of the Experiment Stations. This work, while having for its basis systematic studies, extends into broad fields of agronomy and other lines, such as have to do with the improvement of pastures, or range-lands, and many other similar lines. The same is true of many of the important investigations that have been carried on in the matter of studying noxious plants, as, for example, weeds, etc.

The advanced forestry work of the present also owes its inception, primarily to systematic studies which were begun years ago, and which are still continued in order to form an intelligent and rational basis for many of the advanced problems in this field.

In medicine too, the study of systematic botany has played an important part. It was the general practice in the early days for physicians to be trained in botanical lines, and a great deal of our most important information has been brought out by the work of these same physicians. In fact, it has generally been considered necessary for physicians to be pretty thoroughly posted on botanical matters; hence the close relationship of botany to the practice of medicine has always been recognized. With systematic botany as a basis, the study of materia medica has advanced rapidly and has formed an important item in the development of our work. The differentiation of pharmacy from medicine has also led to further advancement in these lines, and has done much to advance the value of the investigations.

Probably in no other field of botanical science has the applied work been of more value to mankind than in bac-

teriology, surgery, and sanitation. The systematic study of the causes of disease has led to most valuable results, and in nearly all of these investigations the inception of the work can be traced to one or more lines of botanical science. Such, in brief, have been some of the advances in applied botany in this country, and with this somewhat hasty sketch in mind, let us turn our attention to the future and consider what opportunities are before us, and along what lines our efforts should be put forth in order to achieve the highest and best results.

Attention has already been called to the importance and necessity of constantly keeping in mind the fact that in the application of science we cannot be too careful as to the foundation of our work. In the race for results we are too apt to lose sight of this fact, and in the end we find, too late, that our entire fabric has been built of straw and tumbles to earth at the first gust of wind. It is necessary, therefore, in looking to the future development of applied work in this country, that we should turn our attention, not so much to the older men who are already in the field, but to the younger generation who are still to come up, and the training they are getting, or are to get, in the various institutions of learning throughout the country. It is too true that many of our institutions of learning have been slow to recognize applied science; and even now, with all the demand for applied work, little or no effort is being made to put this work on the basis where it belongs. The training in applied lines at this time is meeting with much the same opposition that science itself did when first introduced into our colleges—especially science as taught by laboratory methods, rather than science as taught by handing down from year to year doubtful knowledge long stored in dusty tomes. There was a time, and not so far distant, either, when to be a student in a science course in some of our institutions required considerable moral stamina; but all this is changed with respect to science, yet there still lingers that inherent hostility to all things practical, as is most strikingly emphasized in institutions where applied work, such as agriculture, engineering, etc., is made

a part of the regular course. With the great increase of wealth in this country and the commendable spirit being manifested in the endowment and establishment of institutions of learning, the fact must not be lost sight of that there may be some danger, as has been pointed out, in building up an "educated proletariat," a class who, as specialists, will care more for getting their names attached to abstruse technical brochures than they will for a treatise that will enable some struggling mortal to make life less a burden. Someone has truly said that the danger from education is not so much from its quantity as from its character, so that it is the character of our training that should receive most careful, conscientious and considerate thought.

This leads us now to a consideration of the nature of the training our young men should receive in order to fit them more especially for the opening fields of labor in applied botany, and at the same time make good citizens of them, whether they go into the work in question or some other equally important. Pure science, of course, must form the ground work for this training, but in addition to that there should be parallel with it, throughout the entire course, a rigid system of training in the application of science to the practical affairs of life. It is needless to say that we do not have, anywhere in this country, at the present time, such a course of training in botany; and for this reason the men who go into this kind of work must receive their training in large part after the college doors close on them. I do not wish to be understood as implying that this state of affairs is due to our teachers, for most of them recognize the fact just mentioned and are doing everything in their power to overcome it. The trouble is with our system of education as a whole, but more directly the body politic, which has, ever since mind training began, given preference to the ornamental rather than the useful. Nothing has done so much to weaken this idea in the human mind as science itself, and nothing can so strengthen science in what it can further do in this direction as to teach its broad practical application to the affairs of life. It would seem, therefore, that the time is ripe for some

decided action leading to a clearer understanding as to the methods whereby the increasing demand for men trained in applied botanical work may be met. The National Government alone is spending close on to a million dollars a year in this work, and the demand for the right kind of men far exceeds the supply. In fact, the Government, through lack of properly trained men, has been forced to undertake the training itself, a course which would not be necessary if the proper co-operation could be secured from the colleges. Here is a subject which might very properly be taken up by this Association, and more especially this Section, as it is one in which most of us are either directly or indirectly interested. I have dwelt upon it somewhat in detail, as it has seemed to me the foundation upon which all other matters are built. With the men that we have and the men we can get, what then are some of the problems with which applied botany in the future can hope to deal?

With the opening of new territory during the past few years there has, of course, developed a need for still broader work, for we are now especially pressed for tropical investigations, which we are unable to meet through lack of equipment and lack of properly trained men. Moreover, another and equally important field has been opened through the rapid extension of our population into the arid and semi-arid regions, and the demand from these people for light on many subjects, which we are illy prepared to give. It seems to me that everything points to the fact that the heavy demands for applied botanical work for the next fifty years will be mainly in the field of plant physiology and pathology. The two subjects are intimately connected, and while there will, of course, be many physiological problems pure and simple somewhere and at some time, these problems will be found closely associated with pathological phenomena.

Reverting to our western conditions, arid and semi-arid, there are many questions which demand immediate attention, and which have an important bearing on the future development of the country. Such, for example, are those which have to do with the water supply of plants and with the

bearing of water supply on plant production. Irrigation is now an important factor in our industrial and commercial development, and the problems associated with it must be reckoned with. In the past, the work in this field has been mainly of an engineering nature, such as the question of securing water and bringing it as economically as possible to the plants. Now arise more far-reaching questions, such as how to handle this water in a way to attain the desired maximum results with the least expenditure of time and money. Given water, soil rich in plant food, and proper heat and light, the productive power of plants is great if the requisite knowledge is present as to how best to utilize what nature and art supply. Such problems as these must, for the most part, be worked out in the field, but the field must be made to take the part of a laboratory, for laboratory methods on an extensive scale must be employed.

What is the effect of varying quantities of water on the longevity of a plant; how is the production of fruit and foliage affected by the water supply; how far can time of ripening, color, keeping qualities, and resistance to diseases and insect attacks be controlled through the ability to control the amount of water used? These problems, on their face, appear simple, but they are important ones, and to throw light upon them there must be most careful studies in a number of fields. Chemistry will, of course, enter into these studies, but it must be a living, vital chemistry, if I may use such a term, and not the mere question of ash determinations. Closely related to the problems involved in water supply are those which have to do with so-called alkali soils and their effects on vegetation. A question of supreme importance to the development of our western country is to know more of the effects of various mineral salts, severally and combined, on plants. With such complicated problems as present themselves to the investigator in this field, it is not safe to base any conclusions on the knowledge of how plants behave in a laboratory, where the action of a single salt or simple combination of salts has been determined. The fact that individual plants show marked differences in their ability to resist the poisonous effects of

alkali salts opens up an interesting field in the matter of plant selection and plant breeding. Wherever crops are grown in alkali soils, especially under irrigation, the power of certain of these plants to make better growth and give greater yields than their nearby neighbors, has been noted.

Profiting by these facts, an important field opens in the matter of developing alkali-resistant plants, having the power to give relatively large yields in the presence of an unusual amount of soluble salts in the soil. Some interesting suggestions have been made in this direction by the recent work of Kearney and Cameron, and the same investigators have also pointed out the great economic advantages that may result from the combination of two or more salts which, individually, may be dangerous, but when combined have the opposite effect on plant growth.

The nature of the problems here briefly reviewed shows the broad scope of physiological investigations, for they merge at various places into ecology, pathology, chemistry, and physics. There is, furthermore, shown the futility of attempting to solve such problems along one line of cleavage, for it cannot be done with any degree of satisfaction.

Aside from the problems mentioned, the field for applied work in plant nutrition is large. The physiological roll of mineral nutrients in plants is little understood, and the effects of mineral nutrients on growth, singly and combined, should be explained. The power to control profitable plant production through a better knowledge of plant foods is recognized, but there is yet much to do in the matter of making clear little known or obscure questions on this subject. In the problems connected with the acquisition of nitrogen, however, are to be found some of the most important practical questions in this field. The results already accomplished in this direction, through the use of proper nitrifying ferments, have not been as successful as was anticipated, but this does not indicate that future work may not be made more profitable. There is much to be done in the way of investigating the life history of bacteria inhabiting the root tubercles of legumes, for unless such questions are better understood it

will not be practical to apply our knowledge in any far-reaching way. The time will doubtless come, however, when our knowledge of the nitrifying organisms will be sufficient to enable us to apply, in a much broader way, the use of pure cultures of such organisms in general field work. Already encouraging results have been obtained in this direction, and steps are being taking to extend the practical application of these results as rapidly as circumstances will warrant. The future success of this work will no doubt depend, in large measure, upon the ability to properly grow the nitrifying organisms in large quantities and at an expense which will not curtail their use; and then to be able to distribute the organisms in such a way that the farmer himself may use them at little expense, but with sufficient profit to pay for his trouble. It will be seen, therefore, that while these may appear as simple problems, when looking at them from the purely utilitarian view, there is much work to be done in the laboratory, under rigid scientific conditions, before satisfactory conclusions can be reached.

It is in connection with the problems bearing on plant breeding and the selection of plants better adapted to meet the special requirements, that some of the broadest questions of applied botany can be brought to bear. While, as already explained, plant breeding is more or less of a composite science and, to a certain extent, an art, physiology is after all the basis for most of the work. There is much need for further research work in the field of reproduction and heredity, especially with a view to obtaining light on many practical questions which are bound to come up within the next few years if applied investigations are to have their proper place. Admitting the necessity of these, it would seem that some of the more practical problems that must be considered within the near future will have to do with obtaining light on such matters as the securing of plants adapted to particular purposes and to particular regions. As population increases and competition in all lines of agricultural production becomes keener, the need for securing plants better adapted to certain conditions and which can be produced at a minimum expense;

will become greater and greater. In the South there is already felt the urgent need for improved kinds of cotton varieties that will give greater yields and finer staple, in order that cheap labor of foreign countries can be competed with. There is also a demand for improvement in other plants adapted to the South, which will enable the southern agriculturist to more generally diversify crops.

We have been told at former meetings of this Association, by members of other sections, that within a comparatively short time the United States will not be able to grow the amount of wheat, and possibly other cereals, needed for consumption. These statements are based on our present yields and the increasing demand of population. If the figures are true it would seem important that attention be drawn to the securing of varieties of wheat better adapted to existing conditions and yielding larger quantities of grain. This is a perfectly legitimate field for applied botanical work, and what has been accomplished already indicates that much can be done in the direction of largely increasing the possibilities of this country in the matter of cereal production. What is true of cotton and cereals is also true of many other crops, so that it is unnecessary to go into detail as to what might be accomplished in the way of causing not only an increased output, but improving the quality of the output as well.

Associated with the work of plant breeding, and more or less closely related to it, is another important field which has for its object the studies of life histories of principal crop plants, with a view to determining the environmental conditions necessary for successful growth. This work, of course, covers a broad field, as it involves knowledge of the requirements of climate and soil, and really merges into the broader territory of ecological work. The problems involved carry with them not only the question of plant adaptations, but the matter of introducing new plants from foreign countries and the broader dissemination of plants already existing here and which give promise of more profitable yields under changed conditions of environment.

With proper studies of soil and climate, the possibility of more intelligently defining the areas adapted to certain crops will become greater. After all, however, the vital questions involved in this problem will depend largely upon actual experimentation, as those most familiar with successful crop production know how unsafe it is to generalize in such matters. The success or failure in growing a certain crop often depends on differences in soil and climate so slight that present instruments cannot determine them, although the plant, with its power to respond to immeasurable stimuli, can do so.

In the field of pathology the opportunities for applied work in the near future will be great. We are all agreed that the more or less empirical methods of handling plant diseases has about reached an end. It served a useful purpose in pointing out practical ways of controlling some of the common and destructive plant maladies, and enabled those who were looking to the future to create a sentiment making possible better and more far-reaching work. We do not agree with those, however, who hold that the time is at hand when we can afford to stop the propaganda of actual field treatment. In fact, we are more and more convinced that one of the greatest opportunities for bringing home the practical value of pathological studies will be to undertake at once, on an extensive scale, what may be called demonstration experiments. A propaganda in this field, conducted by and depending upon publications alone, no matter how practical such publications are, will necessarily be slow; but when the work can be carried into the field and be made to serve as an object lesson, the impression made is lasting and convincing.

One of the problems, therefore, for the future, in this work, is how to insure the application of the investigations made, and to so conduct the work that it will all go toward the development of a system of plant pathology which will build up and strengthen the science. Recognizing the importance and necessity for the application of remedial measures in the form of fungicides, to which the foregoing remarks mainly apply, we may turn our attention from this art, for so it is, to other methods of applied work in this particular field of

botany. The future of other lines of applied work all hinges on a recognition of the possibilities within the plant itself, its plasticity and ability to hange, the effects of environment and the means of controlling environment, or controlling the plant to meet the requirements of environment, to the end of securing desired results. Here again, the breeding of plants will enter and furnish the means of overcoming diseases by selection of resistant varieties from those already existing and the creation of new varieties having the desired characteristics. Here, too, arises the question as to what factors govern resistance to disease, and how may these factors be determined and controlled. Why is it that the most successful production of a plant is often reached when its ability to resist the attacks of organisms or to succumb to functional disorders is at a minimum, or, expressing it in a somewhat paradoxical way, why is a plant weakest when it is apparently most vigorous?

Proper knowledge on many of the problems involved in the questions here presented will make it possible to apply it in securing crops at far less risk than at present, and will tend to make the occupation of plant growing less a matter of guess work than it is now. No rational system of pathology can be developed, furthermore, without due attention to proper field hygiene, the rotation of crops, and other similar means of surrounding the plants with healthful conditions. Some of the principal lines of work, therefore, in the future, in this field, will be in the direction of giving a broader application to existing knowledge on the question of treating plant diseases by means of fungicides, to the development of new forms better able to resist diseases and suitable for special conditions, to the handling of plants so as to better adapt them to conditions at the present, and to the improvement of field methods to the end of securing vigorous growth by furnishing conditions needful to the highest production of the crop.

Of the future problems in other lines of applied botany, it is not necessary to speak in detail. Suffice it to say that in the broad field of forestry, agrostology, and pharmacology, systematic botany will always play an important part. In

agrostology, especially, which has now come to be understood as covering the study of not only the true grasses but all forage crops as well, the field for applied work is exceedingly broad. With the rapid settlement of the East and the utilization of our arable western lands for crops, the area for the maintenance of stock is becoming less and less. Thus is developed the necessity for a better understanding of methods of improving and maintaining our pastures. The production of larger quantities of forage from given areas, and the improvement of our range lands to the end of enabling them to support an increasing number of cattle, are some of the other important problems in this field. These broad questions will, of course, involve to a certain extent systematic studies of native floras, the changes which may result from the shifting of plants from one place to another, and the opportunities that may arise from the introduction of new forms and the improvement of those already present.

Within the last few years it is fortunate that a well defined forest policy has been developed, so that in the future the growth of this work will be largely in a distinct field. Botanical investigations, however, will always play a more or less important part in all matters pertaining to the subject, especially systematic studies of the tree floras and the application of these studies to questions having to do with reforestation and the protection of existing forest areas. The applied botanical work, in connection with future problems in pharmacology, will be considerable. Systematic studies of plants used in pharmacy, the introduction and cultivation of such plants with a view to increasing their usefulness, all come within this scope of applied botanical research. The study of tropical plants, which has already been referred to, is also bound to play an important part in the near future in the matter of the development of our insular possessions. As yet, we have very little satisfactory information as to the possibilities of tropical agriculture, especially as concerns our own country; and it would seem that some of the first problems will have to do with systematic studies of the field to determine existing possibilities, with a view to applying them in

the near future in a practical way. There are numerous practical questions having an important bearing on all tropical work which must receive attention before any final conclusions can be reached in regard to the successful growing of crops in these regions. These questions have to do with the interrelation of the plants themselves to the development of the existing system of tropical agriculture, so that really a systematic study of our tropical floras would seem one of the first requisites as offering a key to the future solution of other and more general problems.

Bacteriology, in its relation to surgery and sanitation, has passed out of the field of applied botany, but problems will still arise. Systematic studies of the bacteria may be essential to the successful prosecution of certain phases of this work. It is hardly necessary to refer to these questions in detail, and I may, therefore, conclude this somewhat hasty and general sketch of the possibilities of applied botanical work, as we see them, by again calling attention to a fact which becomes more and more evident as we look into work of this nature, and that is, how thoroughly we are all dependent on others for aid, not only in our own field of science but other fields as well. Like our social fabric, science for science's sake, and applied science, are becoming more and more a delicately complicated system, capable of endless harmonious expansion if viewed aright, but leading to possible endless discord if handled wrong. How essential, therefore, that the broadest spirit of tolerance should be cultivated, for no matter how small or how humble a piece of real work is, somewhere and some time it may be made to form a part of an harmonious whole. While this is a practical age, and while the demand is heavy for practical results, we should not forget that there are ages to come after us—ages that may demand something different from what the majority of us are producing now; and for this reason the laborer in some obscure field should not be forgotten, for it perhaps may be that his work, now little known or understood, may in the future take its place in the building up of mankind.

PAPERS READ.

Some Neglected Factors in Discussions of Heredity. By Geo. J. Peirce, Stanford University, Cal.

Conditions Influencing the Vitality and Germination of Seeds. By J. W. T. Duvel, Univ. of Michigan, Ann Arbor, Mich.

Soil Temperatures and Vegetation. By D. T. MacDougal, N. Y. Botanical Garden, New York, N. Y.

Effect of Acetylene Gas-light on Plant Growth. By Frank William Rane, New Hampshire College, Durham, N. H.

Plant Environment and Plant Diseases. By Frank William Rane, New Hampshire College, Durham, N. H.

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A Bacterial Soft Rot of Certain Cruciferous Plants and Amorphophallus sinense; a Preliminary Report. By H. A. Harding and F. C. Stewart, N. Y. Agric. Exper. Sta. Geneva, N. Y.

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THE FINDING OF PUCCINIA PHRAGMITIS (SCHUM) KORN, IN NEBRASKA. BY J. M. BATES, Callaway, Neb.

A DISEASE OF POTATO STEMS IN OHIO, DUE TO RHIZOCTONIA. BY A. D. SELBY, Wooster, Ohio.

ARACHNIOTUS TRACHYSPERMUS, A NEW SPECIES OF THE GYMNOASCACEÆ. By C. L. SHEAR, U. S. Dept. Agric., Washington, D. C.

AN INSTANCE OF A CHANGE IN THE NATIVE FLORA. BY C. E. BESSEY, Univ. of Nebraska, Lincoln, Neb.

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COMPARISON OF THE DEVELOPMENT OF THE EMBRYO SAC AND EMBRYO OF CLAYTONIA VIRGINICA AND AGROSTEMMA GITHAGO. BY MEL T. COOK, Greencastle, Ind.

STUDIES IN PHYCOMYCETE FERTILIZATION: SCLEROSPORA GRAMINICOLA (SACC.). BY F. L. STEVENS, A. and M. College, W. Raleigh, N. C.

A NOTE ON THE VITALITY OF THE SPORES OF MARSILEA. BY MARSHALL A. HOWE, N. Y. Botanical Garden, New York, N. Y.

NOTES ON AGROSTIS. BY A. S. HITCHCOCK, U. S. Dept. Agric., Washington, D. C.

THE ASCENT OF THE TRANSPIRATION STREAM. BY E. B. COPELAND, Stanford University, Cal.

CHEMICAL STIMULATION AND THE EVOLUTION OF CARBON DIOXIDE. BY E. B. COPELAND, Stanford University, Cal.

THE ABSORPTION OF WATER; A FUNCTION OF THE LIGULE AND STIPULACEOUS TISSUE OF THE GRASSES. BY F. L. STEWART, Merrysville, Pa.

THE PITH CELLS OF PHYTOLACCA DECANDRA. BY HENRY KRAEMER, Philadelphia, Pa.

A REVIEW AND CRITICISM OF THE BOTANICAL CURRICULUM OF SOME OF OUR COLLEGES AND UNIVERSITIES—FROM THE STUDENT'S STANDPOINT. BY E. MEAD WILCOX, Auburn, Ala.

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ADDRESS

BY

J. WALTER FEWKES,

VICE-PRESIDENT AND CHAIRMAN OF SECTION H FOR 1901.

PREHISTORIC PORTO RICO.

It has been customary for the Vice-President of this Section of the Association to present in his retiring address certain general conclusions to which he has been led by his own special studies or those of his contemporaries. But it has not been regarded as out of place for him to outline new and promising fields of research or to indicate lines for future development of our science.

Late historical events have brought into our horizon new fields for conquest and opened new vistas for anthropological study. In the last years the political boundaries of the United States have been so enlarged that we have come to be regarded a "world power," and with this growth new colonies beyond the seas now form parts of our domain. With this new epoch certain broad scientific questions have come to present a special claim on our students, and we have been brought closer than ever before to problems concerning other races of man besides the North American Indian. Great fields of work attract our ethnologists to the far East and the islands of the Pacific, and these new problems will occupy our attention with ever increasing interest in years to come as Anthropology advances to its destined place among sister sciences. It is natural and eminently fitting that attention at this time should be directed to some of the new anthropological problems before us, and I have chosen as a subject of my address, Prehistoric Porto Rico, and the Antillean race which

reached its highest development in our new possessions in the West Indies.

Among all the acquisitions which came to the United States by the treaty of Paris, Porto Rico is pre-eminent from an anthropological point of view. Fourth in size of the Antilles it is the most centrally placed of a chain of islands reaching from Florida to the coast of South America. Before the coming of Columbus there had developed in these islands a culture sufficiently self-centered to be characteristic, and our new possession was the focus of that culture. Here was found a race living in an insular environment exceptional on the Western Hemisphere. If, as the great Anthrogeographers insist, anthropological problems are simply geographical in their final analysis, where can we find a better opportunity to trace the intimate relationship of man's culture and his surroundings? Where was there on the American continent at the time of its discovery a people less affected by contact with other cultures or more truly the reflection of climatic conditions?

It may be truly said that important questions regarding migrations of the early inhabitants of the American continent are intimately related to the cultural character of the prehistoric race which peopled the West Indies. Was this race derived from the great northern or southern land masses, or was it an offshoot from the early inhabitants of Yucatan, the great peninsula of Mexico which projects towards the end of Cuba? Many theories of the peopling of these islands have been propounded, but none are regarded with full confidence. Although this race was the first seen by Europeans, by whom it has been known for the longest time, comparatively little accurate study has been given to it by the anthropologist. Documentary evidences are not meagre, but ethnological data are limited, for the race disappeared within a few generations after its discovery and lost much of its distinctive characteristics by mixture with other peoples. Archeology furnishes more material bearing on the problem than ethnology, but this material has not been correlated, being widely scattered in different museums in Europe and America, and in many

collections which remain in private hands. A great amount of archeological data yet remains hidden in the soil, awaiting the spade of the explorer.

Although English scientific literature on the archeology of Porto Rico is remarkably limited, the subject has attracted several anthropologists whose works are of highest importance. The study of its history and antiquities has been zealously cultivated by several native Porto Ricans, whose publications in Spanish are little known to students in the United States, since some of the most important of these contributions have appeared in local newspapers of the island having no foreign circulation. The main sources for the more important historical works of more modern historians, are standard writers like Oviedo, Las Casas, Hererra, Muñoz, and Iñigo, with notes by J. J. Acosta and rich unpublished documentary material by Tapia y Rivera. The more prominent modern Porto Rican historians are Salvador Brau and Coll y Toste, who deal more especially with historical epoch, while the writings of Padre Nazario, Neumann, Gandia and Torres, many of which are controversial, are important aids in the same lines of research.

No institution has exerted a more stimulating influence on the local study of Porto Rican history than the Ateneo Puertorriqueño of San Juan, which has spacious rooms on the Plaza Alfonso XII, where there is a fine library and a number of portraits of famous Porto Ricans.

A valuable scientific publication on the Indians of Porto Rico, and the only modern Spanish work which follows archeological methods, is by Dr. A. Stahl, a native of the island educated in Germany, who has made many important contributions to the study of the flora and fauna of the island. This work, *Los Indios Borinquenos*," appeared in 1889, and while criticized in unessentials has held its place as a work of high merit.

Prof. Mason's accounts of the Latimer and Guesde collections, practically catalogues, are the most important archeological works which have yet been published on the antiquities of the Antilles. There are many scattered references in the

writings of Stevens, Dr. Cronau, and other authors, which augment this information and practically complete the all too meagre literature of a great subject.

It would be impossible for me in this brief address to do more than outline in a very general way the prehistoric culture of Porto Rico. I have in preparation a more extended account in which I have drawn largely from sources above mentioned, from an examination of many archeological specimens in private collections unknown to science, and a personal study of the island on a short reconnoissance in April and May of the present year.

Ethnology affords us but scanty data in the study of the subject, for the aborigines have been so changed by inter-marriage with other races that little can be identified as belonging to the precolumbian life of the island. Still in the more isolated regions the Indian features can be recognized and certain customs peculiar to the island can be traced to Indian parentage.

There are many Boriquen words in the patuis of the mountainous region, and the rugged valleys of Loquillo, the Sierras on the eastern end of the island, as Yunque and Cacique mountain, still have a wealth of folklore, part Spanish, part Indian, with a mixture of African, which will reveal to the folklorist many instructive phases of this subject. Mr. Spinosa has already published some of these tales in a short popular account, but much in this line yet remains to be done in this isolated, perhaps the most inaccessible region of the island. Many of the mountains in this locality are regarded as enchanted, and about them cluster stories of St. John, the patron saint of the island, mixed with legends of old Indian Caciques and their families.

In his note on the name of the mountain Yunque, Acosta, quoting from a documentary account of Porto Rico by Presbiter Ponce de Leon and Bachillar Antonio de Santa Clara in 1582, written by order of the King, derives the word Loquillo from the name of a Cacique who lived in this high sierra, but was never conquered.

According to Acosta this tradition of the last surviving Ca-

cique of the island has furnished a subject to Sr. Tapia y Rivera for his novel entitled "El Ultimo Borencaño."

All the available evidence supports the conclusion that in the inaccessible region of Porto Rico called Loquillo we must look for the purest Indian blood among the present mountaineers of the island.

In the isolated valleys of this region we still find the old Carib canoe surviving in the hollowed out log of wood by which produce is drawn down the slippery mountain sides. Here are also the old forms of hammocks different from those now generally used. Maize is a staple article of food, and the primitive mills with which it is ground date back to a remote past.

The prehistoric inhabitants of the Antilles from the Bahamas to the coast of South America belonged to one and the same stock, but differed in these minor characteristics which are not racial. The people of the Bahamas, Cuba, Hayti, and Porto Rico, were a mild agricultural race which had lost in vigor what they had gained by their sedentary life. The Caribs, or people of the Lesser Antilles, were more warlike, and their ferocity was known everywhere in the West Indies. Columbus heard of them in his first voyage when he landed on the Bahamas, and on his second voyage his first land fall was on one of the islands where they lived. Although he saw little of the Caribs on this voyage, he learned of Boriquen or modern Porto Rico from some of the captive women, and taking these slaves on board his ship he coasted along its southern shore, at last landing on the western end near Aguadilla, filling his water casks at the famous spring at that place. Although a well known local historian has questioned this as the landing place of Columbus in Boriquen, the evidence supports tradition, and a beautiful monument very properly marks the place where the great Admiral landed in 1493. But while the majority of writers ascribe the discovery of Boriquen to Columbus on his second voyage, Sr. Luis Llorens Torres gives the honor to another, and in a well written pamphlet on "America" has shown in a convincing way that when Martin Alonzo Pinzon separated from the great Admiral on his first

voyage he visited Porto Rico and probably landed on its shores.

Dr. D. Isaac Gonzales Mestizes, as quoted by Sr. Torres, states very clearly the arguments for the unity of the prehistoric people of the West Indies, and shows that the insular Caribs and Boriqueños were practically of the same stock. There is every evidence that while there may have been, especially among the Lucayans, a slight influx of blood from North America, and that the influence of Carib culture was felt on the art of the coast people of Florida and the coast dwellers of other southern States, the Antilleans primarily came from South America. Although Carib and Boriqueños were practically of the same stock they differed somewhat in their mode of life due to climatic influences, their religion, customs, and language.

The former, although confined to the Smaller Antilles, made frequent predatory expeditions upon the more peaceable inhabitants of Cuba, Hayti and Porto Rico, especially the latter, carrying away the women as slaves. Thus we have in the insular Carib communities men and women speaking different dialects, showing idiomatic differences in the Carib and Boriquen speech, and implying amalgamation of the two stocks. The incursions of the Caribs on the eastern coast of Porto Rico continued after the Spanish had made settlements there, and they raided and destroyed the town Naguabo on the river of the same name.

Unfortunately we have no authentic cranium of a typical prehistoric Porto Rican to compare with that of the Caribs, although it is probable that skulls of this race could be found in a systematic scientific exploration of the island, especially in caves in the neighborhood of Utuardo, Ciales, and the more inaccessible parts of the island. The name of the cave, Cueva del Muertos, not far from Utuardo, indicates that it was used for burial or disposition of the dead. These caves contain many religious symbols, as rock etchings, of gods and grotesque forms of idols cut out of stalactites, showing that they were used by the Indians as places of worship, refuge, or possibly of habitation.

When Columbus landed on the island of Guanahani the first native words he heard belonged to a language which was one of the most widely distributed of those of the new world, a tongue which with dialectic variations was the speech from central South America to the coast of Florida. These dialectic differences in the speech of the Antilles aborigines were small, the Caribs of the Lesser West Indies and the Lucayans of the Bahamas being linguistically of the same stock, as has been repeatedly pointed out by several writers, ancient and modern. This same stock had left traces of its language and peculiar culture on the Spanish Main along the coast of Mexico, which facts are significant, but have led to erroneous views of the relationship of the aborigines of Central America, Cuba, Hayti, and Porto Rico.

The accounts of the houses of the prehistoric Porto Ricans by Oviedo, Iñigo, and others are amply sufficient to lead us to conclude that they did not greatly differ from those of the country people to-day. Stone or adobe buildings were not constructed, but a fragile building, the frame of which was tied together with maguety fibers and covered with bark of the royal palm or yuccas and thatched with straw, furnished a home for the prehistoric inhabitants. These houses, like their modern representatives, were raised on posts to avoid dampness and insects, suggesting pile-dwellings, a feature of house construction with which the Caribs were familiar.

In many of the smaller towns of Porto Rico we still find a street lined with these houses built in the same primitive way, inhabited by poorer negroes or peons. Some of these modern buildings are of the rudest construction and practically as primitive as those which Oviedo described four centuries ago.

It appears from early records that at the time of Columbus' first visit the Indians lived in cabins scattered over the island, but that here and there these primitive dwellings were collected in pueblos, one of which is described by Muñoz in some detail. It was situated back from the shore, and consisted of a circle of these bohios surrounding the central house of the Cacique. Two parallel rows of palisades forming an arbor united this pueblo with a lookout

on the beach, which was built somewhat higher and served as a place of observation. It is probable that the plaza enclosed by the ring of houses was the dance place, and that the central house of the Cacique contained the clan idol and other objects used in the cult of the inhabitants.

Similar villages are reported as existing in Cuba and Hayti, and it was probably into one of these that the embassy of Columbus to the Grand Khan was conducted, when they penetrated into the interior of the former island. On their return to the squadron this embassy reported to the Admiral that they were escorted to a special house, probably that of the Cacique, seated on a wooden chair, evidently a *duho* such as we now find in several collections, made in imitation of an animal, and surrounded by natives who also had their appropriate seats. The accounts clearly indicate that the Spaniards were regarded as supernatural beings and carried to the god house of the pueblo, and seated on the chair of the gods.

The furniture of the house of the ancient Porto Rican was limited, but ample. The bed was a hammock made of the leaves of the palm, maguey, or fiber of native cotton. In the mountainous regions of El Yunque primitive hammocks like those of the ancients are still made, and the palm fiber is wholly employed in their construction. Calabashes or cocoanuts served for household implements, as drinking cups, and in the poorer parts of the island are still used for the same purpose. We have every reason to suppose that these objects were ornamented with geometrical figures, but whether the patterns now used in the adornment of these objects have been inherited from a Carib ancestry is yet to be satisfactorily made out.

Clay vessels of rude construction were used by these Porto Rican Caribs who lived along the shore where multitudes of fragments of these objects are found to-day in several localities, one of the best of which is the country about Cabo Roja. These clay vessels are, as a rule, of rude construction, unglazed, their rims commonly adorned with raised heads representing animals of grotesque forms. The likeness of many of these heads to monkeys has led several writers to ascribe

this pottery to races living on islands or the mainland where there are simian genera. There are no monkeys in Porto Rico, where these heads are found, and as they are most abundant along the shore they or the motive of their form are generally ascribed to the Caribs. I have examined several unbroken clay vessels from the island which are undoubtedly of Carib manufacture, all of which were ornamented in relief or intaglio, and regard this supposed resemblance to monkey heads as highly fanciful.

According to the early writers the Carib men and girls had little clothing, but the married women and Caciques wore a woven cloth of palm fiber called *nagua* which apparently resembled the breech cloth with dependent ends. In the warm climate clothing was not needed for warmth and a liberal covering of paint protected their bodies from the heat of the tropical sun and the bites of troublesome insects.

The most characteristic of all objects made by the Caribs were the canoes, with which they navigated from island to island or travelled along the numerous rivers and lagoons. These crafts often reached a great size, and were in some instances made of logs of wood hollowed out by fire and furnished with oars and sails. If there is one characteristic which more than others distinguishes this Antillean culture it is the development of their maritime habits of which these canoes are the objective expression, but this characteristic was highly developed before the race landed on the islands. Canoe building had reached a considerable development in their primitive home and made it possible to move the tribes which brought them to the islands.

The number of stone implements in collections from Porto Rico is very large, including objects of all sizes and many shapes. The arms of warfare were mostly stone adzes and hatchets with wooden handles, war clubs made of ironwood of the island, spears, and possibly throwing sticks. In the collections which were examined no arrow points were found. As a rule, the implements from the Antilles are polished stone, but I have seen two celts which show marks of chipping. Most of these implements were of stone, but Mr. Yunghannis

of Bayamon has in his collection a celt from Porto Rico made from the lip of a conch shell like those used by the Caribs of the Lesser Antilles.

The height of culture attained by the prehistoric inhabitants of Porto Rico, as shown by their pictography, has been variously interpreted, but so far as known the writing of this people was of the rudest kind, consisting of pictures having the same general character as the pictography of the North American Indians. Specimens of this work are abundant in caves and are found on the flat slabs of stones used in the enclosed dance plazas or on isolated boulders.

The soft, easily eroded rock of the island does not retain this palæography for any considerable length of time, especially when exposed to the weather.

In the caves on the island there still remain many excellent specimens of picture writing, some of the best of which are studied near Ciales and Aquas Buenas in the high mountains of the central region of the island. Some of the caves are of great beauty, among the most interesting of the many natural attractions of Porto Rico. They were resorted to by the Indians for religious purposes and later for refuge, but there is no reason to suppose that they were ever extensively peopled, for the ancient Porto Ricans lived in the open and were not trogloditic.

The article published by Mr. Klüg contains all that has yet appeared in print on Boriquen pictography, which will be more fully illustrated in my report on a reconnoissance of the island during the last spring. The figures which were studied appear to be clan totem and other names or symbols.

From the accounts which have been preserved there is every probability that the social organization of the inhabitants of prehistoric Porto Rico was practically the same as that of the American Indians in other parts of America. The unit of organization was the clan, the chief of which was called a Cacique.

It would appear that certain of these Caciques had control over others governing large sections of the island, and that a union of several smaller Caciques for mutual defense occurred

at rare intervals. As a rule there was no such union; Caciques of neighboring valleys were not friendly, often hostile, making raids on each other. In certain sections of the island a Carib chief appears to have raised himself to the position of governor of this region, but in every settlement the Cacique and his immediate relations had a house larger than the others and centrally placed, containing the Zemi or idol of the clan. The power of the head clan man was supreme, his wives, of which there were many, were practically slaves, and descent was apparently in the male line. The Cacique had several insignia of his rank, among which may be mentioned bodily decoration, a gold plate called a guarim worn on his breast and a stone amulet, beautiful specimens of which are now preserved in several collections, tied to his forehead.

The names of many of these Caciques are still preserved as local names on the island, and it would appear that localities were then known by the names of powerful rulers. On modern maps we find the names of Caciques applied to different mountain chains. Dr. Stahl regards it probable that the names of minor Caciques, possibly clan chiefs, are perpetuated in names of the modern towns, Utuado, Yubucoa, Curabo, Cayey, and many others. Aguenaba is commonly stated to be the sovereign ruler of all the island, but his power was certainly not always recognized, and it would be exceptional in primitive society to find one man a ruler of the island of the size of Porto Rico.

Among supposed insignia of Caciques should be mentioned characteristic stone objects of ring form which from their form have been called "Collars." These are often made of the hardest stone beautifully polished and decorated, showing evidences of having been ornamented with inlaid gold or precious stones. The interpretation of these objects is one of the archeological enigmas, for the early historians are silent regarding their use or what they represent. The consensus of modern opinion is that they were worn by the Caciques as insignia of rank, and the form of many of them favor this conclusion. Others are too small and many too heavy to be carried either about the neck or on the shoulders as a kind of bandolier, which facts throw some doubt on the theory that

these objects were ever worn on the person. The older writers are also silent regarding the meaning of the elaborate designs which are cut upon them. A study of these designs on many specimens shows that in some instances they correspond to the head and parts of the body of certain stone idols, and there is every probability that these designs represent forms of clan gods. Acosta, in a valuable note to the last edition of Fray Iñigo's history of Porto Rico, refers to his examination of many specimens of these collars and suggests that these rings represent the bodies of serpents and upon which stone heads were fitted; the whole represented a coiled serpent.

This is not the place to present all the evidence I have gathered to prove that these collar stones represent serpents, but it may be said that in one of the so-called collars which was examined on my recent visit to the island the resemblance to a coiled serpent was so close that its identity was perfect, even the head of a snake being well represented. The animal which it represented was probably a serpent or some mythic reptile with serpentine body.

It may be urged since snakes are so rare and small in Porto Rico that the natives would not elevate a cultus of them to the height these stones imply. But it may be said that stone collars of this kind are not confined to this island, occurring also where serpents are large and deadly. Moreover, the old accounts say the Antilleans had images of snakes, and these are the only objects of serpentine form. Although it is probable that these problematical rings were sometimes worn as insignia, there are many others where this explanation would be impossible.

Among the best polished stone images found in collections from Porto Rico are small figures called amulets, representing frogs, turtles, lizards, birds and other animals. These nicely worked specimens are commonly concave or slightly curved on one side, being tied in position by means of a cord passing through a hole drilled from edge to edge. Some of the writers of the sixteenth century mention the fact that the Antilleans wore these amulets on their foreheads, and the object of the image appears to be to indicate the clan.

As in all primitive society the social organization of the Antilleans was built on a religious foundation; the people were governed by priesthoods which controlled all the public life of the people. Every Cacique was a priest in virtue of his standing in the clan, which was the political unit, and as we shall later see it was the religious and ceremonial unit as well. The whole social and religious organization was knit together by a form of totemism or tutelary clan ancients worship, which I shall call Zemeism.

These priests were called Boii, or sorcerers, and the idols apparently often had the same name as the priesthood. In their ceremonies these priests represented ancestors symbolically and naturally took the names of that which they represented.

The functions of these priests were much the same as those of the priesthood in all primitive society. They performed rites and ceremonies connected with the worship of ancestral gods, located diseases and bodily ills by magical methods and practised an elaborate system of divination, which is described with more or less detail in the several early accounts. Disguised as a Zemi, or hidden behind or near a statue of the same, these priests gave oracular responses, making use of elaborate mechanism to deceive those who consulted the idols as oracles.

One of the most remarkable of these prophecies mentioned by Gomara in the middle of the sixteenth century has become historic. The father of the Cacique Guarionix who ruled one of the five great Caciquedoms of Hayti consulted the Zemi regarding the fate of his gods and people, having prepared himself by fasting and purifications, as the customs of his country required. He received this reply: Before many years there would come to the island bearded men with bodies clothed in mail who with one stroke of the sword would sever men in twain, would bring fire over the land and drive from the earth the ancestral gods, destroying time-honored rites, and make blood flow like water. Gomara comments on this prophecy in his quaint way, adding that all these evils have followed in the wake of the advent of the Spaniards.

In a famous letter in which he described his first voyage to America Columbus stated that the natives of Hispañiola or Hayti were without any religion, but on a later sojourn in their midst he was able to form more accurate ideas of their manners and customs and correct his earlier impressions. He found that instead of being destitute of this universal human attribute they recognized and worshiped many supernatural beings which they represented by idols to which they gave the name Zemis. The Admiral found that they had special houses called temples set aside for this purpose in which these rude idols were set up, and that this cult was practised by fraternities of priests who exercised the healing art and consulted idols for oracular purposes. The idea of a future life was found to be universal among the inhabitants of the island. In a work ascribed to Columbus' son, Fernando, the general character of this religion which the great Admiral, his father, found in the Antilles, is set forth more in detail, and contemporary writers supplement it with an account of the exoteric character of the cultus of the natives of Cuba, Hayti, and Porto Rico.

It is but natural that some of these writers and those of the two centuries following that in which America was discovered should have formed erroneous impressions of the nature of this cultus. Recognizing a well developed idolatry they sought and found in it to their satisfaction a god of good and one of evil, or two supreme deities, analogues of the Christian God and Devil. There could be no more erroneous and misleading explanation of the meaning of Zemeism than this, and the error is apparent when we review the historical interpretations as recorded in later writings. The misinterpretations threw discredit on all that had been written, most of which was strictly accurate so far as statement of facts was concerned, for while the Antilleans may not have had the ethical gods imputed to them by early writers, we need not deny them the possession of a religious sentiment or agree with the conclusions of a prominent Porto Rican ethnologist that everything points to the belief that the Boriquen Indians were wholly destitute of religious ideas. There are to my mind many and

conclusive archeological proofs which practically support what Columbus, Roman Pane, Oviedo, P. Martyr, and others state regarding the religion of the Antillean, although I am unable to accept the interpretation of its nature advanced by others.

In order to determine the nature of the Porto Rican aboriginal cultus let us examine it both historically and archeologically, or as described in the writings of those who saw or knew of it first hand and have recorded their observations, and from a study of archeological material, a great amount of which has come down to our time in the shape of idols and religious paraphernalia.

Fray Roman Pane says that the Haytian Caciques had certain stones called Zemis which they religiously preserve; that each of these has a peculiar virtue; thus one can make grain sprout, another aids women to be delivered without pain, and the third is efficacious in bringing rain.

It will be evident to any one who reads the early accounts of their images that the same names are applied indiscriminately to the idol and the spirit or magic power it represents, indicating that one personates or symbolizes the other.

I shall later be able to give you some idea of the shape of some of these Zemi from available archeological material, but it is sufficient at this point to note that magic powers were ascribed to certain stones. Stone Zemis are the most numerous in all collections from the Antilles. But this was not the only material out of which these Zemis were found, for according to Oviedo and other writers various accounts have come down to us recording the forms of these images. They are said to represent various bizarre animals, frogs, turtles, snakes, lizards and birds. They had many specific names, and according to Fernando Columbus each clan chief had his own tutelary Zemi with a characteristic name, and Gomarra, in 1553, adds that they were named water, corn, safety, and victory. Several Spanish writers state that both sun and moon were regarded as Zemis by the people of Hayti, and according to Charlevoix these luminaries were supposed to have originated from a cave near Cape François in the northern part of the island, where there were two large idols representing

the sun and moon, and a pictograph evidently of the sun, and niches for the reception of minor idols.

It is an instructive and suggestive fact that the human race was believed to have emerged from the same cave, and on their advent upon the earth's surface men had the forms of various animals. The strange parallelism between this belief of the Antillean and that of the aborigines of the continent of America can be readily explained by a common theory, for in both cases these animals were clan totems.

The next aspect of the cult of the Zemis, as derived from historical sources, is also significant in attempts at interpretation. Several of the older authors speak of the custom among the Antilleans of painting their bodies and faces, and it is distinctly stated the designs represented the Zemis. It is stated that the Cacique painted a figure of his Zemi on his body, following in other words an almost universal custom among primitive man of decorating himself with his totem. This usage of the Antilleans, and the statements of early writers that the figure painted on the body represents a Zemi, reveals more clearly than aught else that the design was a totem, or there is good evidence that the totem as used by North American tribes referred primarily to a man's name and mark, and that etymologically the word refers to the pigment or earth used in painting a distinctive mark on the body. A strict abhorrence of incest, and the necessity of bodily marks to distinguish members of the same clan, naturally led to designs on the body which took the form of animals and plants or other natural objects. From their simple method of designating member clans by bodily markings, so that a man could recognize his relatives has sprung a system of theoretical totemism which has been ably described by many well-known writers. Primarily the Zemi which the Antillean painted on his body corresponds with the totem of the North American. Zemeism is practically another name for totemism and, as we shall presently see, a form of ancestor worship.

Certain statements in some of the older writers can be quoted to show that the Antilleans derived the clan from the Zemi by descent. Herrera speaks of Zemis named from an-

cestors, a statement Tejada in his valuable history of San Domingo repeats with addition. These supernatural beings personated by images of stone, clay and wood, or represented in paint on the bodies of the Cacique, are said to be ancestral, or representations of the clan ancients, pointing to the belief that Zemeism was a form of ancients or ancestor worship, the individual Zemis being tutelary clan ancients.

Other indirect evidence of ancestor worship can be found in the descriptions given by early writers of certain objects found in the West Indies.

The sight of human skulls and bones in Carib houses taken in connection with the stories of cannibalism with which the minds of the early discoverers were filled naturally led to the belief that the Caribs were anthropophagous, and the name Carib has passed into literature as a synonym of cannibal.

It appears that the skulls of the defunct were preserved and kept in the houses, and it is probable that the sight of these heads led to the distorted accounts of cannibalism among the Caribs, which was found in the writings of the sixteenth century and copied with gruesome embellishments by later authors. The preservation of the skulls or other parts of the body of their ancestors is simply an aspect of ancestor worship which runs through the Zemi cultus, and is all important in the religious ideas of all the Antillean aborigines. Although these preserved skulls were once so numerous, so far as I know only one specimen of a human skull and body preserved as an object of worship has found its way into the hands of the collector. The object taken from a cave near Maniel, west of the city of Santo Domingo, was figured in my article on Zemis from Santo Domingo, and later by Dr. Cronau in his work on the history of the discovery of America. The body made of woven fabrics with arms akimbo, is in a sitting posture, while the head is a skull covered with cotton fabric, with artificial eyes inserted in the sockets of the skull. This specimen, one of the most instructive of all objects illustrating the Antillean cultus, was undoubtedly reverenced and regarded as an object of worship.

It is instructive in view of the ancestor worship which

this specimen so well indicates to refer to certain mortuary customs of the prehistoric Antilleans as recorded by Oviedo. After describing the custom of wife burial with the dead, he says that in the interment of certain Caciques the natives envelop the body in cotton cloth, place it in a grave which they cover with boughs and sticks, depositing with the dead the objects he prized most highly. The corpse was placed in the grave in a sitting posture on a seat called a *duho*, and for many days after burial areytos, or ceremonial dances, were held in honor of the dead, in which the virtues of the deceased, his many good deeds in peace or war were extolled. No reference is made to the subsequent fate of the skeleton, but it is more than likely that it was later removed from its grave, which may account for the failure of archeologists to find the ancient Antillean sepultures.

The archeological material available for the study of the Antillean cultus is more complete than the historical, for there are several large collections in which many of these objects made of stone and wood are found in different museums in Europe and America, and others still remain on the island of Porto Rico and Santo Domingo, where there are several private collections of great value. The Latimer collection in the Smithsonian and the Stahl collection in the American Museum of New York are the largest in the United States, while the Neumann and Nazario collections on the island of Porto Rico are of great size.

The Zemis from Porto Rico which I have thus far studied are made of stone, but there is every probability that others made of wood, like those known from Hayti and other West Indian islands, will later be found on Porto Rico. The small clay beads, so common in collections from this island, and commonly called Zemis by local collectors, are not regarded as such, but as decorative pottery fragments from broken vessels.

A typical form of Porto Rican stone idol has a triangular form to which, from a conical elevation, Mason has given the suggestive name "Mammiform figures." The general character of these stones, and the various bizarre animal heads

which they represent, answers all the documentary descriptions of Zemis, and the fact that they figured by Charlevoix with the legend "Zemi" proves their identity. This identification has been questioned in some quarters, because in the majority of specimens the lower surface is concave, suggesting that they were used as paint mortars, but in a collection which I have examined at Bayamon this surface is convex and ornamented with incised lines, making it impossible for them to be used as mortars or for grinding purposes.

We find these Zemis differing very greatly in size, in the kind of rock of which they were made, and the artistic finish. It is probable that they were once decorated with gold eyes and ear ornaments which additions have, however, long ago disappeared. They represent frogs, birds, reptiles, and various other animals with bizarre shapes, or carved to represent grotesque human faces with body and limbs, as a rule very reduced in size.

The most problematical structure of the mammiform Zemi is a conical projection which most of them bear on their backs. It suggested to Mason a symbol of the characteristic mountain of Porto Rico and other West Indian islands, the whole stone figure representing the genius of Boriquen or a myth analogous to the story of Typhœus.

It is interesting to note that El Yungue, the highest peak of the island, when seen from the little coast town Loquillo, has an appearance that suggests a conicam Zemi, a central conical elevation with a lateral elevation on each side.

Thus far no Zemis made of wood have been described from Porto Rico, but several are known from Hayti, and the other Antilles. These have been found in special niches in the walls of caves, and when used were seated on god chairs, as several authors have described. In a report on my late visit to the Antilles I shall describe and figure one of the most perfect of these wooden Zemis which has yet been recorded.

From what has been already given regarding the character of the Zemis, as deduced from historical and archeological sources, it is possible to state in résumé the following conclusion regarding the nature of the worship which they illus-

trate. Roughly speaking, Antillean worship was a form of cultus called Zemeism or ancestor worship, the Zemi representing the clan ancient or tutelary god of the clan. These clan gods in stone and wood represented the ancestors of the clan, and were supposed to have by virtue of their forms the magic power of the ancestor.

The figures painted on the bodies of the Caciques represent the clan tutelary beings, each different and characteristic as the clan differed. There is little doubt that when a Cacique was thus painted with the figure of his tutelary in his own conception, as well as in that of his clan, he became that supernatural to all intents and purposes, just as when a pueblo Indian puts on a mask with certain symbols he is transformed into the being which the symbolism of that mask represents.

Not only did each Cacique or clan preserve as an object of worship an idol representing his tutelary clan parent or Zemi, but also his bodily decorations in certain dances and at other times represented that ancestor. In the occult or esoteric way be became a living personator of the ancestors worshiped by the clan of which he was chief. The painting of the body among the Antilleans appears to have taken the place of elaborate masks so common in North America, a practical expedient which the hot climate dictated.

But the Antilleans were likewise familiar with the use of masks in personations of their gods, and while these objects are not directly described as worn in their many ceremonial dances, there can hardly be a doubt that Dr. Chanca had this usage in mind when he wrote certain passages of his letter. That the Antilleans had masks of ceremonial import not only references to them in the early Spanish writers show but the masks themselves abundantly prove. Moreover, many examples of Antillean wooden and stone masks exist in different collections. Some of these, as one in the Capitol at Hayti, are of a size to fit the face; others are too small and too heavy to be worn, so that the probability is that most of these masks had become highly conventionalized in their use. They were not worn, but still functioned for the same purpose as if they were. They represented symbolically the clan or

other Zemi, but face and bodily decoration made their use as coverings redundant. There is every probability they were carried in the hand or attached to rods or other objects by those personating the Zemis.

In strict accord with this interpretation of the symbolic masks of stone and wood are the repeated statements in the early chronicles that they were offered as gifts to those whom the giver thought to be supernatural, an act symbolizing the fealty of the clan god or Zemi to a higher god. This is paralleled with modifications elsewhere in primitive American religions. Moctezuma believing Cortez a god, possibly Quetzalcoatl, sent him a bird snake mask of wondrous workmanship. So, also, the early accounts say that on several occasions the Indians of the Antilles, as symbols of friendship of fealty, sent masks to Columbus. One of these given by the Cacique Guacanagari to Columbus on his visit to Hayti is said to have been made of wood with tongue, eyes and nose of massive gold. This object was no doubt similar to that now preserved in collections, and probably resembled those of stone in the Latimer collection of the Smithsonian. Columbus saw many of these masks in Cuba on his first voyage, and on his return to the ill-starred colony of Navidad on his second voyage was met by an embassy of the same Cacique bearing two masks with gold ornaments as regalia. These masks, no doubt in both cases, were symbolic of the supernatural power or tutelary god of the Cacique. The act of sending them was one of homage and respect of himself, his clan, and the being he worshiped. It is also instructive to note as an evidence of a widespread custom among American aborigines that with one of these symbolic masks Columbus also received as a present a belt ornamented with shells, stones and bones recalling, as Dr. Cronau has pointed out, the wampum of North American Indians.

The worship of ancestors, which comes out so plainly in all proper interpretations of Zemeism, appears likewise in the care of the dead and the whole nature of mortuary customs of both Carib and Boriqueños. From the existence of many skulls in the houses of the former it has been supposed that these people were anthropophagous, but it is probable, as has

been shown above, that many of these skulls, carefully wrapped in basket ware or woven cotton coverings, were the crania of their own ancestors preserved with pious care and used in the rites and ceremonies of ancestor worship. These skulls, artifically covered with cotton fabrics and attached to bodies of the same material, were seated on stone god chairs or *duhos*, and deposited in caves, but they were also kept in houses as the early records state.

We find in the descriptions of the Antilleans accounts of exercises called areitos which are interpreted as ceremonial dances in which ancestors were personated. Great stress is laid by most writers on the fact that in these dances songs commemorating deeds of valor or personal worth of the dead were sung, and all agree that they occurred on all ceremonial occasions. The short descriptions which have come down to us indicate, as a rule, that these dances had a religious motive in which the praise of the ancestors was only one, although a most important part. The areito was undoubtedly a ceremonial dance, composed of rites, public and secret, accompanied by semi-religious games, dances, and various other elements. In these areitos the priests personated their ancestors as do the pueblos in their Katcinas, but with far different paraphernalia.

Although there is material available in documentary history for that purpose, it would take me too long to describe these ceremonial dances in full, and I will refer to one of typical character which may be identified as a ceremony to the goddess of growth, which was one of the best known ceremonies of the prehistoric Antilleans having been described by Gomara, Herrera, Hakluyt, and others. Charlevoix gives a picture, somewhat fanciful of the dance accompanying this ceremony which is copied by Picart on his great work on the rites and ceremonies of all people. The occurrence of this ceremony was announced publicly by a town crier directed by the Cacique, and consisted of a procession to the temple or house in which the image of the Earth Mother was placed. The Cacique led the line of dancers, and when he had approached the entrance to the temple seated himself near the idol, vigorously beating a drum, to the sound of which the participants danced.

The procession was composed of men, girls, and women. The men had their bodies painted black, red, green and other colors, and wore many ornaments of shell, and feathers in their heads. The girls were wholly naked, and the women bore baskets of cakes ornamented with flowers.

As each member of the procession approached the idol of the growth goddess she raised the flowers and baskets of cakes to the god as offering with prayers. And later these offerings were divided into fragments and distributed among the people. The public dance was preceded by secret rites, but we have only fragmentary references regarding the nature of these rites. Benzoni records that the idol was decorated before the arrival of the procession, and there are several references to the sprinkling of the same with prayer meal as occurs in all Hopi ceremonial rites. And mention is likewise made of ceremonial purification as a preparation for the rites.

We have very fragmentary historical accounts of the shape of the idol of the Earth Mother, and the figures given by Charlevoix and Picart are probably more or less fanciful. In these figures this idol has five heads, each representing different animals, with that of the deer in the center. As Pane and P. Marytr says that the Haytians have several names for an idol in the form of a woman, one of which means earth and the other mother, I have ventured to translate her name the Earth Mother, and identify the ceremony as one for growth of crops.

Time does not permit me to describe in detail this ceremony or to outline the reasoning which has led me to interpret it as a festival of the goddess of growth, but there is no doubt that the rites and dance before the image of the goddess Tierra have for their object the growth of vegetation and increase of the crops upon which the Haytian relied for food.

Judging from the general life of primitive man we are forced to the conclusion that probably the majority of all the Antillean dances mentioned by the early Spanish writers were of a religious nature. In them, as is most universal in primitive ritual, rhythm played a most important rôle,

and they were accompanied by a rude drum made of a log of wood or by a rasping of a stick over an elongated gourd incised with parallel lines. This latter instrument may be of African parentage, but it is still represented in Porto Rican folk music and sold to visitors as characteristic of the island.

The poetic beauty of the songs recounting the deeds of their ancestors in their areitos did not escape the attention of some of the chroniclers. We are tempted to recognize in the Boriquen, a national anthem of the Porto Ricans, some strains of melody which may have survived from aboriginal times, and the weird music which one hears from the palm-covered house of the mountaineer may yet be found to contain Carib survivals. We know that by royal edict of Ferdinand in 1513 the right of holding their areytos or ceremonial dances was allowed to the enslaved Indians, and perhaps there may yet survive in the cabins of the lowly at least some of the melody of the prehistoric Porto Rico.

Whether there were special plazas set apart for these dances is a question of some interest, and in this connection may be mentioned certain level places surrounded by lines of stones set on edge, found in several localities in the island. These enclosures are ordinarily supposed to have been constructed for the game of ball called batey, and are circular or rectangular in shape. Some of these structures can still be seen in the mountainous districts near Utuado, and the sources of the Bayamon river, but the majority have been destroyed; the flat bounding stones having been used for pavements or other purposes. It is conjectured that the rows of stones which form the periphery of these enclosures are the remains of seats for spectators; the judges or Cacique occupied a seat in the middle as Oviedo describes. While ball games may have taken place in them, it seems to me highly probable from their mode of construction, situation, and other characters, that they were also used as dance courts in which were celebrated some of the solemn religious ceremonies of the clans.

From this imperfect sketch and much more of like import, which will be developed later in a more extended account of Antillean archeology, certain general conclusions have been drawn

which have a relation to the early migrations of man on the American continent. The peopling of the Antilles is believed to have occurred at a comparatively modern date and to have been brought about by an offshoot of the Arawak stock migrating in old times from South America to Boriquen via the chain of islands forming the Lesser Antilles.

The peculiar culture of this race attained its highest development in Hayti and Porto Rico, where conditions were most favorable to its growth. Cuba and the Bahamas had likewise been peopled by the same race, but in neither of these islands had the culture attained the height it reached in the smaller islands mentioned. The Lesser Antilles exposed to inroads from savage South American tribes of the same stock as those of Porto Rico, were unable from physical and agricultural conditions to reach the height of the more central islands. They were practically the starting points of the foraging parties, and Boriquen was constantly attacked by these marauders.

The cradle of the prehistoric Antillean was, I believe, on the banks of the Orinoco and its tributaries in the great republic of Venezuela. His ancestors belonged to the Aruwak stock of South America. His culture having naturally developed certain distinctive features in fluviatile waters among great forests, its ancestors became maritime and pushed away from the coasts from island to island until it came to Boriquen. There a part of the race became sedentary, but with the adoption of this kind of life it lost much of its early prowess and daring, retaining only certain linguistic and other kinship with South American relatives.

In the same way the Caribs, another race related but in some respects, distinct in others, swarmed out of the same Orinoco valley, coasted from island to island in the wake of its predecessor, extending its incursions to Florida and our Southern States. This race also yielded to the insular environment. and commingling its blood with that of the former developed the characteristic culture we have called Antillean. These two peoples, at first tribally distinct, though members of the same great stock by admixture and as a result of environment

were fast coming to be homogeneous and thoroughly amalgamated when the advent of the Europeans practically exterminated the Boriqueños and reduced the insular Carib to a wretched remnant of one of the purest native races of America.

Imperfect as are the data now available or possible to determine the nature of the prehistoric Porto Rico, I will remind you that the problem is that of all the Antilles. We are on the threshold of a great subject for judging from collections of antiquities from the neighboring islands. I have no hesitation in saying that a vast amount of new material awaits the advent of the archeologist and ethnologist in these islands.

It is reported that the terrible volcanic eruptions on the island of St. Vincent have blotted out the last remnant of the Caribs, but while local settlements of these people may have been destroyed the race is not yet extinct on the Lesser Antilles, and is well represented at various points in South and Central America. There remain also the kindred people in Guiana and Brazil, to a knowledge of whose life and customs Im Thurn, Ehrenreich, and Von den Steinen have added so much, and the relatives of the Caribs and Arawak scattered among the numberless tribes of the Orinoco valley, that *terra incognita* of American Ethnology.

It is from a view of this kind over a special field that we get some idea of what there is for the anthropologist to do in the future and the new problems recent events have disclosed, but I have called your attention to only one of the many in the science of man. There are many more of equal or greater importance awaiting solution which late years force especially on the attention and study of American anthropologists. The unknown anthropological material opened to us by territorial growth is vast, and it is natural that our anthropologists surveying this great unknown awaiting research should be serenely conscious of the future of our science. We have, indeed, every reason to be proud of the past achievements of American anthropology, in which this section has played a most creditable part, but the work before us is destined to yield still greater results, shedding a still brighter luster on American science.

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ADDRESS

BY

JOHN HYDE,

VICE-PRESIDENT AND CHAIRMAN OF SECTION I FOR 1901.

SOME STATISTICAL AND ECONOMIC ASPECTS OF PREVENTABLE DISEASE.

Of all the destructive forces of nature, those diseases of the human body whose reference to specific micro-organisms constitutes so brilliant an achievement of modern science have ever been the most profound and far-reaching in their influence upon human affairs. Directly productive in their ordinary incidence of at least one-third of the entire mortality of the world, and the remoter cause of probably half as much more, they form an unintermittent and a powerful factor in the question of population. In Europe and the United States they annually lay prostrate from 65,000,000 to 70,000,000 people, and although all but some 3,000,000 recover, it is, in a large proportion of cases, with an impairment of vital force that is a positive and serious, if not a measurable, disability in the after-struggles of life. Such, however, is the constancy of the common contagious diseases of Europe and North America that the public mind is but little impressed with them. It accepts them as belonging to the established order of nature, and does not yet realize the importance of the issues involved in their possible extinction, or even in that great diminution of their destructiveness of which the progress of sanitary science and preventive medicine has already given us the pledge.

Not so is it with those grander manifestations of the malig-

nant powers of nature which have been witnessed at more or less frequent intervals from the very earliest ages, and which, sweeping over the world like the sword of a destroying angel, have been connected with some of the mightiest events in the history of the human race. The oriental or bubonic plague, the black death, the sweating sickness, Asiatic cholera, and yellow fever have come as tidal waves in that sea of mortality whose ordinary ebb and flow we witness in the fatality of typhoid, malarial, and scarlet fevers, influenza, tuberculosis, diphtheria, and other communicable diseases of daily occurrence.

Nothing in all history exceeds in thrilling interest the record of the pestilential visitations from which the human race has suffered. During the Christian era alone there have been twenty pestilences that have swept the entire known world, and at least thrice within that period from one-half to three-fourths of the human race has been destroyed. One of the two most momentous events in history, the exodus from Egypt, was the direct result of a pestilence; the captivity of the Jews was delayed 122 years by the plague that fell upon the army of Sennacherib, while Thucydides tells us that nothing reduced the Athenian power more than the plague or contributed more largely to the downfall of Athens. Of other instances of the destruction of armies and fleets, of the subversion of social and political systems, and of the demoralization of nations, I cannot speak particularly; nor can I include within the scope of this address any discussion of the effect of the plagues of former ages on the population of the world—a problem rendered exceedingly difficult of solution by its relation to the vexed question of the populousness of ancient nations, and by the uncertainty attaching to those striking and at least partially successful efforts of nature to make good the waste of life by which every pestilential visitation has been followed.

While we have no assurance that, in spite of the strictest sanitary regulations, the civilized world will not again be visited by an epoch-marking pestilence, any more than that some long-slumbering volcano will not repeat the catas-

trophe of Pompeii or St. Pierre, our chief concern is with those kindred diseases which have become naturalized in every clime, and which, from the equator to the arctic and antarctic circles, may everywhere be held accountable for the largest part of the ills of suffering humanity. Even in those eastern countries in which cholera still carries off its victims by hundreds of thousands in a single year, the ordinary mortality from endemic fevers exceeds in any five-year period the mortality from the more dreaded epidemic; so that in the eastern and western hemispheres alike it is the prevention; not so much of a sudden cataclysm of disease as of the daily waste of human life and the unceasing wail of human suffering, that calls for the earnest attention of the scientific investigator, the philanthropist, and the statesman.

But what evidence have we that preventable disease constitutes so large an element in the world's mortality as to justify the use of such terms as I have employed? For an answer I would point you to the reports of the United States Census, those of the health departments of various States and cities, of the Registrar-General of England, and of State or municipal authorities of almost every civilized country.

Twenty-five years ago contagious or communicable diseases were supposed to be confined to the class known as zymotic, a designation that for classification purposes has almost passed out of use. The most signal triumphs of bacteriology were still to come, and if certain diseases were believed by men of clearer vision than others of their time to be preventable, it was only because such diseases, while marked, each one of them, by the strongest individuality, possessed certain important characteristics in common, and some of them, at least, had shown an amenability, limited, probably, even more than was supposed, but entirely beyond question as to its existence to sanitary measures.

In those days the theory of spontaneous generation had powerful advocates, and it was was not until the final disappearance of that scientific heresy, coincidently with the discovery of the specific germs of tuberculosis, Asiatic cholera, diph-

theria, and other diseases, that not only the diseases classed as zymotic, but all others depending upon a specific germ, were recognized as, at least theoretically, preventable.

It was the opinion of Gen. Francis A. Walker that the deaths reported at the Census of 1880 fell short of the actual mortality of the census year by 40 per cent. While for certain States and Territories containing 37.9 per cent. of the total population of the country the Census Office is no longer dependent on the enumerator, I am not inclined to place the total number of deaths reported in 1900 at more than 75 per cent. of the number actually occurring, especially as an addition of one-third to the number reported would only raise the total mortality to 18.2 per thousand against a corrected rate of 17.8 per thousand in the registration area. Taking the census figures as they stand, however, we find a mortality in the United States in a single year of 209,819, or 20.2 per cent. of the whole, from diseases that, with unimportant exceptions, would formerly have been classified as zymotic; of 111,059, or 10.7 per cent. of the whole, from tuberculosis; of 105,971, or 10.2 per cent. of the whole, from pneumonia, and of 29,475, or 2.84 per cent. of the whole, from cancer, with various minor diseases that need not be enumerated, the aggregate from theoretically preventable disease being at least 45 per cent. of the total number of deaths.

With three times the mortality chargeable to typhoid fever tuberculosis occupies the first place in this terrible category, as responsible for one death in every nine. Not only is it found among all the diversified physical conditions of our far-extending country, but there is no portion of the world exempt from its ravages. We think of Havana as the home of yellow fever, and yet in that city, in the ten years ending with 1899, the total mortality from tuberculosis was nearly four times as great as that from yellow fever, one death in every six being chargeable to its ravages. In Rio de Janeiro, in 1900, it was accountable for one death in every five; in Germany its victims number 170,000 per annum; in Great Britain its ravages are so great that the expectation of life at birth would be increased over two and one-half years if con-

sumption were eliminated, and over 3.7 years if there were no deaths from any tuberculous disease. Mountainous and sparsely populated Switzerland contains 50,000 consumptives, and in far-off New Zealand more than 10 per cent. of all deaths are attributable to it, the percentage in the capital city of Wellington in the year 1900 being no less than 15.8.

Almost equally destructive and of as general distribution throughout the temperate zones is pneumonia, which, while claiming as its victims, sooner or later, one in every five of the population of Montana, carries off one in every ten, or nearly, even in such States as Louisiana and Mississippi with a still larger proportion in many foreign cities, both of the northern and southern hemispheres.

And what shall be said of the various fevers which swept away 42,202,148 people in British India, by actual registration, in the ten years ending December 31, 1898? Although cholera was rife during that entire period, carrying away three years out of the ten more than half a million victims per annum, its entire mortality was only 4,239,067—appalling figures indeed, but only one-tenth of the mortality from fever.

Surely, in the face of such figures as these, any reasonable confidence in the prevention or even the substantial mitigation of this waste of human life must be based on something more than the mere assurances of sanguine investigators and experimentalists. Happily, we have sufficient ground for our belief in the measure of success that has already been attained. From almost every part of the civilized world a reduction in the death rate is reported. In the United States, of the eight States (including the District of Columbia) having registration laws, all except Vermont report a lower death-rate for 1900 than was reported for 1890, and the increase in Vermont is confined to the rural districts. Of the twenty-three cities of 100,000 inhabitants or upward in 1900, in non-registration States, and for which a comparison is practicable, seventeen, containing an aggregate population of 6,470,796 and widely separated geographically, report a reduced death-rate as compared with the year 1890. The

death-rate in France in 1901 was 12 per cent. less than in 1851, and in Germany in 1900 25 per cent. less than in 1871. Austria and Hungary, Switzerland, Sweden, and the Netherlands report reduced death-rates that are still more significant because based on comparisons of decades or quinquenniums. Of ten European capitals, nine report a lower rate of mortality in 1896 than their respective averages for the preceding ten years, and while the death-rate in London in 1900, as compared with the average for the preceding decade, shows a reduction of only one per thousand, even so inconspicuous an improvement in the public health as is thus indicated means the saving of 4,418 lives in a single year. The seven colonies of Australasia also report a saving of one life per thousand per annum in the three years ending with 1897, as compared with the three years ending with 1893, while the city of Buenos Ayres, which I select for reference on account of the completeness and general excellence of its vital statistics, reports an annual average death-rate of 19.1 per thousand for the five years 1895-99, as compared with 24.7 per thousand from 1890 to 1894, and 26.8 per thousand from 1885 to 1889. But in all this array of figures there is nothing more significant than the fact that the increase in the duration of life in Great Britain recently necessitated the construction of a new life table, in which the expectation of life at the age of ten years is shown to be 1.668, at twenty 1.621, at thirty .886, and even at eighty .118 years greater than under the former table, there now being out of every 100,000 persons of the age of ten years 3,183 more who will live to be forty, 3,459 more to be fifty, 3,207 more to be sixty, 2,491 more to be seventy, and 1,600 more to be eighty years of age than was the case only forty years ago. These illustrations are for the most part taken at random from a mass of evidence that leaves no room for doubt that the general death-rate of the civilized world is rapidly diminishing.

As regards the combating of those particular diseases which, theoretically at least, are the most easily controlled and give the greatest promise of yielding to repressive measures,

the place of honor should be given to the magnificent work that has been done in Cuba under the administration of the United States. The scientific demonstration of the fact that yellow fever is propagated by the mosquito, and, it is believed, by the mosquito only, has led to the complete extirpation of that dread disease from a city that has been its home for nearly 200 years.

The reduction of the mortality from diphtheria since the introduction of the antitoxin method of treatment forms one of the most interesting chapters in the history of vital statistics. In Switzerland and the Netherlands the mortality has been reduced by one-half, while in France, Germany, Austria, and Belgium there were only one-third the number of deaths from this disease in 1898, per ten thousand of the population, that were reported in 1894, the year preceding the introduction of the new method of treatment. From returns received from six States and nineteen large cities of the United States by the U. S. Commission to the Paris Exposition of 1900, it would appear that in 1894 the fatality from diphtheria in the States and cities reported upon was 29.6 per cent. of all cases, while for the four succeeding years it was only 21.6 per cent. In two States it fell from 29.7 per cent. in 1894 to 14.6 per cent. in 1898. In Massachusetts it was 28.3 per cent. in the four years 1891–94 and 14.9 per cent. from 1895 to 1899. In Philadelphia it has fallen from 31.96 per cent. in 1896 to 17.97 per cent. in 1900, the annual decline being an unbroken one. In St. Louis the decline has been from 35.46 per cent. in the six years ending with 1894 to 15.67 per cent. in the six years ending with 1900, with a ratio of only 8.78 per cent. in the 2,347 cases actually known to have been treated with antitoxin. The first six months of the antitoxin treatment in France reduced the mortality in 108 cities 65.6 per cent. Cracow reports a decline of 60 per cent., while in Dresden only 8.1 per cent. of all cases proved fatal in the four years, 1895–98 against 34.2 per cent. of all cases in the four years 1891–94. From the Antipodes the colony of New Zealand reports a reduction of exactly 50 per cent. in the mortality from this

disease in the five years ending with 1900, as compared with the corresponding period immediately preceding.

The total mortality from typhoid fever in the United States, as reported by the Census of 1900, not only constitutes a larger proportion of the total mortality from all known causes, but also represents an absolutely higher typhoid fever death-rate than was reported by the Census of 1890. The statistics for the non-registration area, however, are acknowledged by the Census Office to be incomplete, and it is possible, though hardly probable, that the addition of the figures that are lacking would render the comparison less unfavorable. In the registration area, containing a population of 28,807,269, or 37.9 per cent. of the whole, there is a marked decline both in the number of deaths from typhoid fever relatively to population and in the ratio of typhoid fever deaths to deaths from all known causes, the former having declined from 46.3 to 33.8 per 100,000 living and the latter from 23.6 to 19.2 per 1,000 deaths. But even the statistics for the registration area, taking that area as a whole, are not strictly comparable, and it is not until we examine the reports for each of the eight States (including the District of Columbia) for which a comparison can properly be made, that a perfectly satisfactory conclusion can be arrived at. Then we really find an indisputable and in the main substantial reduction in the death-rate from typhoid fever in every principal division of a region of 96,306 square miles, of fairly diversified physical conditions and containing a population of 14,328,832, in the exact proportion of three urban to two rural. And yet there are more significant figures even than those reported by this important group of States—more significant because not based merely on the mortality of two single years, a period that scarcely affords an adequate basis of comparison in the case of a disease so large a proportion of the mortality from which occurs in connection with epidemic outbreaks. The death-rate from typhoid fever, per 10,000 inhabitants, has fallen in Massachusetts, with but one break in the continuity of the decline, from 8.2 in 1871–75 to 2.4 in 1896–1900, and in London, England, from 2.4 in 1871–80 and 1.9 in

1881–90 to 1.4 in 1894–95 and 1.2 in 1896.* State reports show that in Massachusetts, as in some of the most populous cities of Europe, there is a relation too obvious to be disregarded between a reduced typhoid death-rate and improved sanitation, the death-rate in the New England commonwealth having declined as the per cent. of the population supplied with public water has risen, while in Berlin and other German cities and also in Vienna and Brussels the decline has been coincident with an improved water supply and the construction of sewers.

Still, there are so many notable and unlooked-for exceptions to the general decline in the mortality from typhoid fever, both in the United States and abroad, that our expectation that the ravages of this disease will eventually be brought to an end is founded rather upon our knowledge of its etiology than upon what has already been accomplished in that direction. Kober has tabulated 195 epidemics of typhoid fever, mainly in England and the United States, that have been traced to the milk supply, and Schüder has catalogued 650, more than half of them in Germany, of which 70.8 per cent. were said to be due to the water supply, 17

*It is surprising that the voluminous report of the Twelfth Census on Vital Statistics should contain so little of that direct evidence which must necessarily be in the possession of the Census Office of the effect of municipal sanitation on the death-rate from preventable disease. It may interest coming generations to know that between June 1, 1899, and May 31, 1900, one colored female cigar-maker died in the United States from disease of the bones and joints, and it may be well to place on record the melancholy fact that every 1,000 deaths from alcoholism in the United States includes nine-tenths of a male person under one year of age, but it is hard to understand why particular attention should be called to the fact that of white persons between 25 and 34 years of age dying of typhoid fever (a disease to which not even a predisposition can be congenital) the highest death-rate was among those having Scandinavian mothers, when the entire report with its 2,168 quarto pages fails to show what cities report, respectively, an increase or a decrease in the death-rate from a disease that has proved more amenable to preventive measures on the part of municipalities than any other afflicting the human race.

per cent. to milk (rarely used unboiled in the countries of continental Europe, hence the low per cent.), and 3.5 per cent. to other foods. Surely the prevalence of a disease that rarely if ever occurs except through the contamination of food or drink by the most loathsome of all germs is a blot on our boasted civilization, and only requires that its origin and mode of propagation shall become generally known to be speedily wiped out of existence by an almost indignant public sentiment.

Tuberculosis is another disease the statistics of which, while not uniformly encouraging, afford ground for hope that its ravages may be stayed. In the United States the death-rate from this cause, per 100,000 of population, declined, from 1890 to 1900, in the cities of the registration States, from 293.5 to 208.7, in the rural districts of the same States from 181 to 137.1, in registration cities in other States from 239.9 to 207.7, and in the total registration area from 245.4 to 190.5. For the country as a whole, the apparent decline is from 122.3 to 109.9, but the figures for both periods are unquestionably much too low.

While reports for single years are less likely to be misleading in the case of tuberculosis than in that of a disease occurring epidemically, they are obviously less conclusive than returns covering consecutive or other comparable periods of five or ten years each, and comparisons based on reports such as those of the State of Massachusetts, the cities of London, England, and Philadelphia, Pa., and the seven colonies of Australasia are of far greater significance than any based on the Census, entirely aside from that defective work on the part of the enumerators which has so greatly impaired the value of the Census returns.

In Massachusetts the death-rate from tuberculosis per 100,000 of population has fallen from 411 in 1851–55 and 346 in 1871–75 to 231 in 1891–95, and 217, 208, 194, 187, and 185, respectively, in the five years 1896–1900. In London the mortality from phthisis per 100,000 of population has declined from 286 in 1851–60, 284 in 1861–70, 251 in 1871–80, and 209 in 1881–90 to 202, 189, 191, 174, 183, and 173 in the

six years 1891–96. In Philadelphia, in the four consecutive five-year periods between 1881 and 1900, the rate per 100,000 was 308.4, 268.7, 232.6, and 210.7. In Australasia it has fallen from 122.2 in 1881–85 and 114.3 in 1886–90 to 102.5 in 1891–95 and 92.7 in 1896–98, each of the seven colonies reporting a marked and almost unbroken decline. Of less significance, but by no means without value as representing climatic conditions of a different type from any of the foregoing, is the statement that the number of deaths from tuberculosis in the city of Havana in the three years 1899–1901 was 56.6 per cent. less than in 1896–98, and 36.1 per cent. less than in 1893–95, the city meanwhile having a gradually increasing population.

So many other instances might be cited of a decline in the mortality from tuberculosis in regions of widely differing physical conditions that there is no room for doubt that this disease, which has ever baffled the skill of the physician and is still accountable for one-tenth of the total mortality of the temperate zones, is gradually becoming less destructive, without any established connection, such as exists in the case of typhoid fever, with improved sanitary conditions and certainly without reference to the discovery that it is a germ disease. Endemic as well as epidemic diseases have their ebb and flow, and just as cancer is rapidly increasing in the civilized countries of both hemispheres, so, conversely, is tuberculosis diminishing. If with this apparent natural subsidence there be conjoined such results as may reasonably be looked for from that better understanding of the pathology of the disease which has followed—somewhat slowly, it must be admitted—the discovery of the tubercle bacillus and from the demonstration, now all but complete, of the communicability of bovine tuberculosis to man, the early years of the twentieth century should forever be rendered memorable by an enormous reduction in the mortality from this dread disease.

Scarlet fever is another disease the steadily decreasing mortality from which is not wholly referable to the preventive measures of the sanitarian or the skillful treatment of

the physician, but whose diminution in frequency and destructiveness is to be attributed in large measure to the gradual attenuation of its specific virus. As a cause of death in the United States, per 100,000 of population, it declined, from 1890 to 1900, in the cities of the registration States, from 16 to 13, in the rural districts of the same States from 8.5 to 7.4, in registration cities in other States from 14.6 to 12.9, and in the total registration area from 13.6 to 11.5. So great has been the decline in its mortality in Massachusetts in forty years that the deaths resulting from it in that State between 1876 and 1895 were 25,000 fewer than they would have been had the death-rate prevailing from 1856 to 1875 been maintained. In London the mortality per 100,000 has declined from 113 in 1861-70, 60 in 1871-80, and 33 in 1881-90 to 26 in 1891-93 and 20.7 in 1894-96. In other parts of England, both urban and rural, as well as in Scotland, Ireland, Germany, Italy, Sweden, Norway, and Denmark, there is a marked decline in the mortality from this cause, while in Australasia the ratio of deaths to population in 1891-95 and in 1896-98 was less than one-tenth of what it was in 1876-80.

If the statistics of whooping-cough and measles, diseases that were accountable for at least 22,824 deaths in the United States in 1900, seem to afford less encouragement to the sanitarian than those of typhoid and scarlet fevers, tuberculosis, and diphtheria, it is not because whooping-cough and measles are in any less degree subject to the laws that govern the transmissibility of communicable disease, but because they are peculiarly diseases of infancy, and their ravages are to a large extent among the children of the poor. The very fact, however, that the high rate of mortality chargeable to them is so largely a matter of environment justifies the expectation of a steadily declining death-rate from these diseases with that general amelioration of the condition of the poor to which so many powerful agencies are being directed.

The reports of the Twelfth U. S. Census give alcoholism as the specific cause of 2,811 deaths in the United States in 1900. Inasmuch as 2,061, or 73.3 per cent. of such deaths, were reported in the registration area, containing only 37.9 per cent.

of the total population, and that for so much of the country as contained the remaining 62.1 per cent. of the population, the enumerators had to rely for information as to the cause of death mainly on surviving members of the families to which the deceased persons belonged, there can be no question that the actual number of deaths from alcoholism was very much in excess of the number reported, notwithstanding that the non-registration area contained a relatively smaller urban population than the registration area. This implies an amount of degradation and misery, of shame and suffering, that is absolutely appalling, and yet the United States will compare favorably, as regards its mortality from alcoholism, with any other beer or spirit-drinking country. The investigations of the Harveian Society make it probable that in London one-seventh of all adult deaths are directly or indirectly due to the consequences of alcoholic excess; in England, generally, intemperance is the direct cause of one per cent. of all male deaths between 25 and 65 years of age; in Prussia the deaths from delirium tremens among males have averaged over one thousand per annum for many years in succession, and in Belgium, with a smaller population than the State of New York, the male deaths from that cause in the twenty years ending with 1889 averaged 330 per annum. While this is not a matter for sanitary regulation, as understood in this address, and there is little prospect of any salutary change in the drinking customs of the world, any considerable restriction of drunkenness and its attendant evils would be so far-reaching in its economic effects that the inclusion of alcoholism among preventable diseases of serious consequence needs no justification.

The mortality from smallpox is in inverse ratio to the stringency of the measures, always including compulsory vaccination, adopted for its repression. Time was when for entire countries, year after year, smallpox was accountable for one death in every ten or twelve. Now it is not unusual for a majority of the world's most populous cities to be exempt from its ravages for several years in succession, and the occurrence of one death in a thousand deaths will excite sur-

prise and apprehension. But it is entirely unnecessary to compare the present with the past to establish the efficacy of preventive measures in the case of smallpox; contrasts sufficiently conclusive are furnished by different countries and even by different States of the Union in our own times. In 1900 the States of New Hampshire, Vermont, Connecticut, and Nevada had no deaths whatever from this disease, 17 other northern and western States had an aggregate of only 72, and 7 others an aggregate of 110, making a total of only 182 deaths from smallpox in a region embracing 51.4 per cent. of the total area of the country, and containing 41.7 per cent. of its total population. During the same period twelve southern States, together with the Territory of New Mexico, the whole constituting a region 40.5 per cent. smaller and 24.7 per cent. less populous than the foregoing, had 15 times as many deaths from smallpox. Is this a matter of climate? Not in the smallest degree can it be said to be such. The fact that throughout the entire north temperate zone two-thirds of the annual mortality from smallpox occurs in the six months having the lowest temperatures warrants the assumption that the equally rigid enforcement of the same preventive measures, north and south, would result in a lower rate of mortality in the latter than in the former. That the proportions are reversed is due to the greater difficulty of enforcing repressive measures in the southern States, owing to the presence of a large—in some cases preponderant—negro population, among which, as compared with an equal number of whites, the mortality from smallpox is as 12 to 1. The difficulty of enforcing preventive or remedial measures among the poor, the ignorant, and the superstitious, is likewise the difficulty with which the government of India has to contend, and the result of which we see in the fact that in the ten years 1889–98 the deaths from smallpox in that country averaged 93,332 per annum, ranging from 42,046 to 160,217, or from 20 to 75 per 100,000 of population and from 5.8 to 20.9 per thousand deaths from all causes. And yet even the highest of these death-rates indicates an enormous saving of life as compared with the conditions that prevailed over

the whole of Europe up to the discovery of vaccination by the illustrious Jenner.

While sporadic cases of smallpox, not necessarily fatal, may continue to occur in even the most progressive and best governed of cities, this disease, so far as the more enlightened nations are concerned, is practically a disease of the past, and the few moments devoted to its consideration in this address are justified not so much by the possibilities of the future as by the example it affords us of a former bane of humanity brought under absolute control and made one of the least destructive of the various causes of death.

Two other once formidable diseases may be mentioned as having been virtually exterminated by hygienic measures. For two centuries scurvy was the scourge of the British navy, the deaths attributable to it exceeding those in war and in all the peculiar calamities attending life at sea put together. Now it is of rare occurrence. Similarly, beri-beri was, prior to 1884, a veritable scourge of the navy of Japan, but the 9,516 cases in the six years 1878–83 were reduced to 765 cases in the six years 1884–89, and of these 718 occurred in the first year of the six.

Several of the diseases to which reference has been made in this address are prime factors in that fearful waste of infant life which is going on all over the world and with which even the highest civilization seems unable adequately to cope. But while, taking the figures of the registration area of the United States for 1900, 60.8 per cent. of all deaths from diphtheria, 62 per cent. of those from scarlet fever, 82.6 per cent. of those from measles, and 95.2 per cent. of those from whooping-cough are of children under five years of age, these are by no means the only diseases, theoretically preventable, that contribute to an excessive infant mortality. The United States Census of 1900 reports among the deaths of children under five years of age 93,118 from diseases more or less directly connected with the process of alimentation, 63,071 from diseases of the respiratory system, and 8,854 from accidents. Included among the foregoing are 22,787 deaths from inanition, debility, and atrophy, synonyms, to no small extent, of starvation and neglect.

The United States Census statistics for 1900, while probably more defective in regard to infant mortality than in any other respect, show that while only 12.1 per cent. of the entire population was under five years of age, the reported mortality under that age was 30.8 per cent. of the total number of deaths at known ages. During the ten years ending with 1900 the ratio of deaths under five years of age to the total mortality in New York City averaged 39.6 per cent., in Philadelphia 34.8 per cent., in Baltimore 37.8 per cent., and in Chicago 41.2 per cent., while the Census shows for the single year 1900 40.7 per cent. in Texas, 41.5 per cent. in Oklahoma, 41.6 per cent. in New Mexico, and 46.7 per cent. in Indian Territory, political divisions containing no large cities and yet each reporting a higher rate of infant mortality among the white population than among the colored.

Glancing at the reports of certain typical foreign countries, we find the empire of Japan with 36 per cent. of its total mortality in 1898 under five years of age, and the seven colonies of Australasia in the same year with 34.3 per cent., the city of London with 43.4 per cent. in 1896, and the city of Buenos Ayres, now the fifteenth city of the world in point of population, with 42.1 per cent. in the five years 1897–1901.

A very large proportion, usually from 60 to 66 per cent. of the total mortality of children under five years of age occurs in the first year of life, and an increasing recognition of the importance of the death-rate at this most fatal period is resulting in the statistics for such period being given greater publicity and becoming in many cases more promptly available than those for the five-year period. This is the reason of my being able to include in this address the death-rates under one year of age in 1901 for a large number of the principal cities of Europe, for but few of which I have yet been able to obtain figures for the five-year period.

Grouping these cities by countries it is found that the deaths under one year in 33 principal cities in England and Wales constituted 26.6 per cent. of the total mortality at all ages; in nine large cities of France, including Paris, 15.6 per cent.; in the four largest cities of Belgium 25.1 per cent.; in Amsterdam

and The Hague 27.1 per cent.; in Stockholm, Christiania, and Copenhagen 27.0 per cent.; in four principal cities of Austria-Hungary, not including Vienna, 23.6 per cent.; in the eleven largest cities of Germany, not including Berlin, 37.7 per cent., and in the three largest cities of Russia 40.2 per cent. The low ratio in the cities of France is the result of the low birth-rate, and it is a fact of great significance that the exclusion of Paris and Lyons from the computation raises the percentage to 24.3.

Except to the adherents of that almost extinct school which regards wars, pestilences, and other swiftly destructive agencies as performing a beneficent function in maintaining the equilibrium between population and the means of subsistence, this high rate of infant mortality is an unmitigated evil, affording the amplest if not at present the most encouraging field for the sanitarian and hygienist.

As long ago as 1884 Sir James Paget computed the annual loss to the domestic, agricultural, and industrial classes of England and Wales from sickness at £11,000,000 sterling. This was at an average valuation of less than five dollars per individual per week, the professional classes, with only 18 per cent. less loss of time, being excluded from the computation. Allowing for the difference in population and in value of labor, a similar computation for the United States would give a total almost fabulous in its amount. Forty-seven per cent. of the deaths from typhoid fever occur between the ages of twenty and fifty; the business and professional elements of our population are largely affected by it, and on an estimate of three hundred thousand cases of typhoid per annum an annual loss of $150,000,000 from sickness from typhoid fever alone does not seem excessive. Sixty-four per cent. of consumptives also die between twenty and fifty years of age mostly after protracted illnesses, in the course of which the well-to-do have had recourse not only to the highest medical skill but to changes of climate involving costly travel.

In the days when plagues and epidemics were of frequent occurrence the growth of cities was retarded and commerce diverted into new channels. The struggle between capital

and labor dates back to the black death in England, when for the first time laborers combined for the protection of their own interests. The relation between epidemics and fluctuations in the price of food is also easily to be traced, and even the value of land was directly affected by the plagues of the middle ages.

An enumeration of the agencies through which disease is known to be transmissible makes it manifest that there is scarcely an act of life that has not its peculiar dangers. Chief among such agencies are water and ice, prime disseminators of the most deadly of pathogenic bacteria, and milk and butter, the former a proved transmitter of typhoid and scarlet fevers, diphtheria, and tuberculosis. Flies may bring to your kitchen or dining table or to the provision store or market stall from which your household is supplied the germs of the most deadly diseases, and mosquitoes, as shown in the fascinating work of the accomplished Permanent Secretary of this Association, are the specific transmitters of malarial and yellow fevers. Cats have conveyed scarlet fever, smallpox, and, there is reason to believe, diphtheria, and rats are one of the chief agencies in the distribution of the bubonic plague and in the transmission of trichinosis. Books, money, and street-car tickets have all been found to be conveyors of disease germs, and this may also be said of public drinking cups and of the cup used in common in religious ordinances. Wood pavements, the sweeping of streets without previous watering, and the wearing of trailing skirts on the streets, are all sources of danger. Expectoration in public places is so generally recognized as a menace to the public health that many cities, not in all respects the most progressive, have police regulations prohibiting it. School children putting the ends of lead pencils into their mouths; promiscuous kissing, especially of babies; unchecked sneezing; the use of public brushes and combs; indiscriminate handshaking; public telephones, and even, as recently pointed out by the London *Lancet*, the opening of letters at the breakfast table, may all be the means of communicating disease.

Fortunately, many of these agencies suggest the means by

which their destructiveness may be held in check. An abundant supply of water, brought from a region free from the possibility of contamination, and carefully protected from contamination after being impounded; the periodical examination of dairy cows, of the water they drink, and of the inclosures in which they are kept; the exclusion of flies and mosquitoes from dwellings and the systematic destruction of mosquitoes in their breeding places; the more complete isolation of persons suffering from contagious diseases, with such other measures as would be the outcome of a generally enlightened public sentiment on the subject of the transmissibility of disease germs, will go far toward checking the long train of evils for which the agencies enumerated are to so large an extent responsible.

Were it possible to arrest the annual waste of life and annual loss of time from sickness by one supreme act of sanitary legislation, while our duty would be plain, I confess that I should regard the immediate outcome with the gravest apprehension, so tremendous would be the economic results. The change, however, can only be gradual, and social and economic conditions will adapt themselves to it. So far as its effect on population is concerned, no serious misgivings need be had. The prevention of that waste of infant life which is so fearful to contemplate will only be to give further impetus to that reduction of the birth-rate which is reported from almost every civilized country, while a too great pressure of population upon the means of subsistence will be prevented by the operation of those various automatic and prudential checks with which every student of the theory of population is familiar. Without calling in question the truth of the proposition for which so many writers on population have contended, namely, that the power of reproducing life exceeds the power of maintaining it, the fact that among all enlightened and progressive peoples not only is the increase of wealth more than commensurate with the increase of population, but that there is a more general distribution of the necessities and comforts of life is surely a sufficient guarantee that the average unit of population is more than equal to the task of its own maintenance.

It must not be forgotten, moreover, that the promise of a considerable mitigation and possibly of the final extinction of the loss of life from certain diseases fatal to man carries with it a like promise concerning the communicable diseases affecting domestic animals, the pecuniary losses from a single one of which have been known to reach $100,000,000 a year, greatly increasing the price of meat as well as checking the growth of the livestock industry and discouraging its pursuit. With regard to the food supply in general, sanitary science will not more quickly relieve the world of the ravages of contagious disease than agricultural chemistry will increase the productivity of the soil and entomology and vegetable pathology put an end to the ravages of insects and of plant diseases. When it is remembered that the losses from the depredations of insects are conservatively estimated at $400,000,000 per annum, and that the average annual loss from rust in the wheat-growing region of the United States is the equivalent of the annual bread requirements of twenty-five millions of people, it will at once be recognized how much can be done in these directions toward relieving any increased pressure of population upon the means of subsistence.

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THE GENESIS OF PITTSBURG AS A SEAT OF IRÔN MANUFACTURE. BY J. B. JOHNSTON, Pittsburg, Pa.

SOME CONSEQUENCES OF THE TRUST MOVEMENT. BY H. T. NEWCOMB, Philadelphia, Pa.

A STUDY OF THE DAIRY STATISTICS OF THE TWELFTH CENSUS OF THE UNITED STATES. BY HENRY E. ALVORD, U. S. Department of Agriculture, Washington, D. C.

THE PASSING OF THE HIRED MAN ON FARMS. BY LE GRAND POWERS, Census Office, Washington, D. C.

VIEWS OF A COUNTRY ROADSIDE. BY W. J. BEAL, Michigan Agricultual College, Agricultural College, Mich.

THE TIMBER TREES OF OHIO AND THEIR ECONOMIC USES. BY WILLIAM R. LAZENBY, Ohio State University, Columbus, Ohio.

THE NECESSITY OF CO-OPERATION BETWEEN THE FEDERAL CENSUS OFFICE AND STATE STATISTICAL OFFICES. BY CARROLL D. WRIGHT, Department of Labor, Washington, D. C.

THE CHANGE OF POSITION, DURING THE NINETEENTH CENTURY, OF THE BUSINESS CORPORATION. BY SIMEON E. BALDWIN, Connecticut Supreme Court, New Haven, Conn.

THE PROGRESS OF IRRIGATION AS DISCLOSED BY THE RETURNS OF THE TWELFTH CENSUS. BY F. H. NEWELL, U. S. Geological Survey, Washington, D. C.

PROGRESS IN INSURANCE ENGINEERING. BY EDWARD ATKINSON, Boston, Mass.

THE PRACTICAL HANDLING OF WOODLANDS. BY GIFFORD PINCHOT, U. S. Department of Agriculture, Washington, D. C.

PUBLIC PROTECTION OF PRIVATE SAVINGS. BY JAMES H. BLODGETT, U. S. Department of Agriculture, Washington, D. C.

PROBLEMS AND POSSIBILITIES OF A DEPARTMENT OF COMMERCE. BY JOHN FRANKLIN CROWELL, Bureau of Statistics, Treasury Department, Washington, D. C.

LOCAL LIFE BY LOCAL TIME, EXPRESSED IN STANDARD TIME. BY EDWARD S. WARREN, Newton, Mass.

VOLUNTARY ASSOCIATIONS AMONG CUBAN WORKING PEOPLE. BY VICTOR S. CLARK, Washington, D. C.

MUNICIPAL INSURANCE AGAINST UNEMPLOYMENT IN EUROPE. BY HENRY J. HARRIS, Department of Labor, Washington, D. C.

SOCIAL BACTERIA AND ECONOMIC MICROBES, WHOLESOME AND NOXIOUS. A STUDY IN SMALLS. BY EDWARD ATKINSON, Boston, Mass.

THE DEVELOPMENT OF AMERICAN COMMERCE—PAST, PRESENT, PROSPECTIVE. BY O. P. AUSTIN, Bureau of Statistics, Treasury Department, Washington, D. C.

RECENT LIGHT ON THE PER CAPITA WHEAT CONSUMPTION QUESTION. BY HENRY FARQUHAR, Census Office, Washington, D. C.

MUNICIPAL GOVERNMENT IN THE PHILIPPINES. BY CLARENCE R. EDWARDS, War Department, Washington, D. C.

THE FORMATIVE PERIOD OF A GREAT CITY: A STUDY OF GREATER NEW YORK. BY WM. H. HALE, Brooklyn, N. Y.

SECTION K.

Physiology and Experimental Medicine.

OFFICERS OF SECTION K.

Vice-President and Chairman of the Section.

W. H. WELCH, Baltimore, Md.

Secretary.

F. S. LEE, New York, N. Y.

Member of Council

J. McK. CATTELL.

Sectional Committee.

C. S. MINOT, R. H. CHITTENDEN, D. S. LAMB.

Member of General Committee.

A. M. BLEILE.

(No papers were read before Section K at the Pittsburg Meeting.)

EXECUTIVE PROCEEDINGS.

EXECUTIVE PROCEEDINGS.

REPORT OF THE GENERAL SECRETARY.

The fifty-first meeting, held in Pittsburg, from June 28 to July 3, may be held to be fairly typical of the general development of the Association during the last few years, and as one which goes far toward realizing some of the more serious purposes of the organization.

The total number of members in attendance was 431, which places the meeting far up toward the head of the list, so far as this feature is to be taken into account, and the roll includes an unusual proportion of the worthiest names among American men of science. Especially large attendance in physics, chemistry, mechanics and engineering may be attributed to the opportunity afforded the members of inspecting the great number of manufacturing establishments in and about Pittsburg, which exhibit some of the most modern and interesting examples of the applications of the branches in question. This feature of the meeting was most fully exploited by the local committee, about fifty excursions having been arranged, some of which entailed the charter and use of large river steamers for an entire day. The arrangements for the excursions and for the general entertainment of the members were on a larger scale than anything attempted at recent meetings of the Association, the local committee having collected and at its disposal a fund of $9,000.00 for this purpose. In face of such splendid liberality it must be added, somewhat ungraciously perhaps, that the agreement with the headquarters hotel was so loosely made that exorbitant rates were demanded of those who found it necessary to occupy quarters near the center of business interest of the Association.

A census of the papers read before the several sections and affiliated societies shows that 320 papers and addresses were given, in addition to the various lectures by the presiding officers of these organizations and the other special lectures in the evening sessions, which would probably bring the total up to nearly 350. An analysis of the special papers discloses the fact that their titles were distributed among the separate branches of science as follows:

Mathematics and astronomy	24
Physics	59
Chemistry	69
Mechanical science and engineering	23
Geology and geography	26
Zoology	28
Botany	79
Anthropology	30
Social and economic science	22

The membership shows a steady increase, the total number at the close of the sessions being about 3,500 (as compared with about 2,800 at the close of the Denver meeting, September 1, 1901), and the financial affairs of the Association are also in a very satisfactory condition. A notable event in this connection was the transfer by the request of the Permanent Secretary of $2,000.00 from his funds to the permanent fund in the hands of the Treasurer, a result largely due to the skilful business management of the affairs of the association by the Permanent Secretary, which called out a special vote of thanks by the Council.

But little was done in the way of new legislation of importance. A single Amendment to Article 20 of the Constitution was proposed by which the words "for one week or longer" are to be omitted. This amendment will come up for action at the next meeting, and would have the effect of allowing meetings of less than a week's duration to be held under the action of the Council. This section now reads as a result of an amendment completed at this meeting:

ART. 20. The Association shall hold a public meeting annually, for one week or longer, at such time and place as may be determined by vote of the General Committee, and the preliminary arrangements for each meeting shall be made by the Local Committee, in conjunction with the Permanent Secretary and such other persons as the Council may designate. But if suitable preliminary arrangements cannot be made, the Council may afterward change the time and place appointed by the General Committee, if such change is believed advisable by two-thirds of the members present.

As a result of other amendments other portions of the Constitution now read as follows:

ART. 9. The officers of the Association shall be elected by ballot by the General Committee from the Fellows, and shall consist of a President, a Vice-President from each Section, a Permanent Secretary, a General Secretary, a Secretary of the Council, a Treasurer, and a Secretary of each Section; these, with the exception of the Permanent Secretary, the Treasurer, and the Secretaries of

the Sections, shall be elected at each meeting for the following one, and, with the exception of the Treasurer and the Permanent Secretary, shall not be re-eligible for the next two meetings. The term of office of the Permanent Secretary, of the Treasurer, and of the Secretaries of the Sections, shall be five years.

ART. 18. The Council shall consist of the Past Presidents and the Vice-Presidents of the last two meetings, together with the President, the Vice-Presidents, the Permanent Secretary, the General Secretary, the Secretary of the Council, the Secretaries of the Sections, and the Treasurer of the current meeting, of one Fellow elected from each Section by ballot on the first day of its meeting, of one Fellow elected by each Affiliated Society, and one additional Fellow from each Affiliated Society having more than twenty-five members who are Fellows of the Association, and of nine Fellows elected by the Council, three being annually elected for a term of three years, etc., etc.

ART. 23. Immediately on the organization of a Section there shall be a member or Fellow elected by ballot after open nomination, who, with the Vice-President and Secretary and the Vice-President and Secretary of the preceding meeting and the Members or Fellows elected by ballot at the four preceding meetings, shall form its Sectional Committee. The Sectional Committees shall have power to fill vacancies in their own numbers. Meetings, of the Sections shall not be held at the same time with a General Session. The Sectional Committee may invite distinguished foreign associates present at any meeting to serve as honorary members of said committee.

By the action of the General Committee the next meeting of the Association will be held at Washington, D. C., December 29, 1902, to January 3, 1903, and will be the first held during the newly aranged convocation week as arranged and agreed to by more than fifty of the more prominent American Universities. The General Committee failed to take the usual step of indicating the probable time and place of the second meeting to follow, the consensus of opinion being that it would be profitable to await the result of the mid-winter meeting before a decision is reached as to the desirability of such arrangements in the future.

At the request of representatives of the organizations concerned the American Anthropological Association and the National Geographic Society were made affiliated societies for the Pittsburg meeting.

Of the reports of committees that on the relations of the journal SCIENCE to the Association may be taken to be of the greatest importance to the general policy of the Association. The report as adopted by the Council is given below:

COMMITTEE ON THE RELATIONS OF THE JOURNAL SCIENCE WITH THE ASSOCIATION.

This committee is able to report that the arrangement by which SCIENCE is sent to members of the Association, appears to be advantageous to the Association and to the advancement and diffusion of science in America. At the beginning of the New York meeting two years ago when the plan was adopted the membership of the Association was 1,721, whereas it is now about 3,450. The Permanent Secretary states that the money derived from the initiation fees of new members has sufficed to send SCIENCE to all members of the Association for the eighteen months during which the arrangement has been in effect. In order, however, that the finances of the Association may be on a satisfactory basis without depending on the initiation fees of new members, and in order that the publishers of SCIENCE may not lose by the arrangement the membership must be 4,000 and should be 5,000. We recommend that special efforts be made to increase the membership to at least 4,000 at the time of the Washington meeting.

We recommend that we be authorized to renew for the year 1903 the present contract with the Macmillan Company, according to which SCIENCE is sent to all members of the Association in good standing on the payment of $2 for each member from the funds of the Association.

Professor Simon Newcomb, the Chairman of this Committee, is abroad, but it is known that he concurs in its recommendations.

(Signed) CHARLES S. MINOT,
G. K. GILBERT,
R. S. WOODWARD,
J. McK. CATTELL,
L. O. HOWARD.

The general proceedings of the Association, inclusive of action by the Council of general interest, but which did not come before the General Sessions, are as follows:

The first General Session was held in Music Hall, Carnegie Institute, on Monday, June 30, at 10 A. M., with the retiring President, Dr. C. S. Minot, in the chair.

After the meeting had been called to order, the following invocation was offered by the Rev. Lemuel Call Barnes, D. D.

O God, we thank Thee that this Universe is intelligent. We thank Thee that we are permitted to study it; and we thank Thee that the more we study it the more we see that it is filled with thought. We thank Thee that it is our duty to look, and work, for the joy of discovery; for the great thrill that comes to any man who finds some new trace of intelligence in this world.

We pray Thee help us to understand it better and better, and let Thy blessing rest upon this gathering, which is intended to stimulate a knowledge of Thy Word.

We thank Thee, O God, that it is a universe: That there is one Law that pervades it all. We pray Thee help us to trace this back farther and farther, until we come to the ultimate reality, and if it be Thyself, divine, infinite, perfect Love, we pray Thee help us to submit ourselves and to surrender our lives gladly to the conception of this ultimate reality and to the promulgation of this ultimate Truth to those who know it not. Be close to every officer and speaker in all this gathering here in Pittsburg, and grant that there may be left a quickened intellectual life in our community, because of the coming of these searchers of divine Truth among us. And as they return to their homes may they carry with them that which will make their work as investigators and teachers still more effective in the beginning of this new century: In the Name of Him who has shown us most of Thyself, even Jesus, the Carpenter of Nazareth. *Amen.*

Dr. Minot, in introducing the President-elect, Professor Asaph Hall, U. S. N., spoke as follows:

My duty is very brief. I come here as the retiring officer of the Association to have, as the last act of my administration, the pleasant duty of handing over the responsibilities to one whom we all honor in the highest respect, and who stands for a very lofty ideal of scientific research; one who has attained, what many scientific men fail to attain, a reputation which extends far beyond the realms of science, practically speaking, for to him was accorded the privilege of discovering one of those features of the heavens which appeal to the imagination, the Satellites of Mars.

To the popular mind perhaps this great discovery stands as the most prominent service of my successor. I speak not for myself, but as the mouthpiece of competent Astronomers who have told me that this discovery, great as it is, represents only a small part, and not perhaps the greatest part, of the services which Professor Hall has rendered to astronomical science.

This Association is more indebted to him personally for many years of faithful service, of great helpfulness, and I esteem it personally the greatest possible honor that after having been, myself, President of this Association, I should have the pleasure of turning over the duties of the office to Professor Hall.

Professor Hall then called upon Dr. W. J. Holland, Director of the Carnegie Museum and Chairman of the Local Committee, who made the following remarks:

Mr. President, Ladies and Gentlemen: I deem it a very high honor to be permitted, on behalf of the Hon. J. O. Brown, Chief Magistrate of the City of Pittsburg, and on behalf of the Hon.

J. R. Murphy, Chief Magistrate of the City of Allegheny, as their representative in behalf of the municipality, to welcome here to-day the American Association for the Advancement of Science.

We recognize, Mr. President, the fact that your Association represents, in the very highest degree, that intellectual vigor and that spirit of scientific research which made the Nineteenth Century one of the most memorable of all the centuries, and which promises to make the Twentieth Century the century of unparalleled achievements. These cities welcome you to-day as those whose brilliant discoveries have made possible to a very large extent the industries which are pouring wealth into the laps of our people. If there be any city in this Union which owes a debt to men of Science, and which should endeavor to foster scientific research, it is this great city which depends more than any other upon the brains of men scientifically trained in technical schools in college and in university, for everything which tends to make her great.

I am commanded, under the appointment which I have received, to declare to you, Mr. President and members of the Association, that the gates of this city are wide open to you, that you may come in and partake of our hospitality. I am bidden to invite you to participate with us in the celebration of Independence Day, and I am commanded to inform you that the President of the United States will be with us upon that occasion as the guest of the city, and it is the hope expressed by the Chief Magistrates whom I represent that we may all celebrate this great day together. (Applause.)

I beg to remind you, Mr. President and members of the Association, that these two cities, with their outlying suburbs and municipalities, constitute an aggregation of population amounting to-day to nearly 750,000 souls. Were they all brought together under one government, which some of us devoutly hope may soon occur, the greater Pittsburg would be the fifth city in rank in the Union in the matter of population, as it is the fifth city in the volume of business which it transacts through its clearing house.

It is as the representative, therefore, of no mean city that I welcome you into our midst to-day asking you to participate in that traditional hospitality upon which we who live here in what Bancroft has called the Gateway of the West pride ourselves. Permit me to remind you incidentally that you are on historic ground. It was here that the stripling surveyor who afterwards came to be known as the Father of his Country won his first laurels. It was here that the first blow was delivered by Anglo-Saxon men in that mighty war the thunders of which reverberated around the world and which eventuated in the displacement of the lilies of France by the lion of St. George, later to be supplanted by the Stars and Stripes. Through these valleys which we hope

to show you, flanked on either side by great manufacturing suburbs, for four or five decades poured that mighty army of invasion, greater than any army that swept in mediæval times from north to south of Europe going forward to take possession of the continent across which it has swept until it has reached the shining western sea, over which it is now pressing forward to far-off Indian Isles.

This city has been the scene of many great movements. Many great movements have been born here. Permit me to remind you that the great Republican Party held its first great Convention in Lafayette Hall, a building which has long since given place to one of the palaces of trade. It was here that a large part of the munitions of war which were used to quell the spirit of disunion in this land many years ago were forged in our furnaces. Here to-day much of the armor for our ships of battle is made, and the rails which bind the commerce of the country together, and much of the machinery which drives her manufacturing industries is created.

Welcome to Pittsburg! The greater Pittsburg! of which her own Poet has sung:

My father was a mighty Vulcan;
  I am Smith of the land and sea;
The cunning spirit of Tubal-Cain
  Came with my marrow to me.
I think great thoughts strong-winged with steel,
  I coin vast iron acts;
I orb the impalpable dream of seers
  Into comely lyric facts.

I am Monarch of all the Forges,
  I have solved the riddle of fire,
The Amen of Nature to cry of Man
  Answers at my desire.
I search with the subtle soul of flame
  The heart of the rugged Earth,
And hot from my anvils the prophecies
  Of the miracle-years leap forth.

I am swart with the soots of my furnace,
  I drip with the sweats of toil;
My fingers throttle the savage wastes,
  I tear the curse from the soil.
I fling the bridges across the gulfs
  That hold us from the To-Be,
And build the roads for the bannered march
  Of crowned humanity.

Mr. Chairman, it gives me pleasure to yield to my friend and colleague, Col. Samuel H. Church, known as Poet, Historian, Novelist, and man of affairs, who as Secretary of the Carnegie Institute, in the absence of the President of the Board, which he greatly regrets, will extend a welcome to you on behalf of the institution which, together with the municipality, has invited you here to-day.

Col. Church spoke as follows:

Mr. President, Fellow Members, Ladies and Gentlemen: Science is not wholly unknown in Pittsburg. When the papers announced that our great monster the Diplodicus was on view here one of the Trustees of this Institute hastened out and demanded that he should immediately be shown that eighty-foot Opidilduc. The objects we have on view are calculated to expand the mind of youth. It was only last week that a gentleman was going up the stairs to the Art Gallery with his little boy. When they came suddenly upon that splendid masterpiece of all time, ever fresh and young in the charm of magnificent womanhood, the little boy said, "What is that, father?" "Why, that, my son, is the Venus of Milo." "Well," replied the little fellow, as he gazed at the armless wonder, "I did not know they had trolley cars in those days." That boy's mind worked in an *a priori* groove. Somewhat like him was the little girl who when shown the dwarf, and told that he was 40 years old and only 28 inches tall, remarked, "Good gracious! He must have been brought up on condensed milk."

Pittsburg is glad to have you here. But, when you come to the discussion of your great problems, and behold us listening, open-mouthed, do not be surprised if you feel like the man in Goldsmith's Deserted Village:

> While words of learned length, and thunderous sound
> Amazed the rustics ranged around;
> And still they gazed, and still the wonder grew
> That one small head could carry all he knew.

Of industrial Pittsburg, of which Mr. Anderson is soon to speak, you will hear much and see much while you are here. She takes the crude materials from the teeming bosom of our mother Earth, wherever they may be found, and transmuting them into forms of utility and beauty, distributes them again unto the remotest habitations of human society. This gives her a tonnage by river and rail which exceeds the tonnage by river and rail of any other city in the world. Her rail tonnage is three times greater than that of New York, double that of London, four times that of Paris, and greater than the rail tonnage of New York, Boston and Chicago combined! (Applause.)

But while these unparalleled manufactures have given Pittsburg great wealth, population and power, it would be but the idle boast of Belshazzar to say that commercial supremacy is the *ultima thule* of her people. She has the handsomest Court-house in the world. Her schools and churches abound. She spends a quarter of a million dollars annually on her parks. She has twelve miles of boulevards where the clang of the trolley-car is forever prohibited; she has given many famous names to science, literature and the arts; she maintains, by popular support, one of the three symphony orchestras of America. (Applause.) She has in hand the endowment of a great school of Technology, and her rich men are beginning to give of their surplus wealth to the expansion of our intellectual and spiritual life, stimulated thereto by one whose monument you have but to look about you to see, in this Carnegie Institute. (Applause.)

Mr. President, to me the most inspiring thing about your illustrious Association is the continuity of your work. The threads of your researches run back from this meeting into the misty investigations of dead centuries. How essential it is that in doing the world's work men should labor together. How impotent is all individual performance or renown when we would ascribe infinite achievement to any one human atom. No great discovery has been made, no conquering fact developed, but, first to last, consciously or unconsciously, has grown from the consecutive thought of earlier workers. Hipparchus, the first of the astronomers, sweeping the heavens with his yearning eye, was able to count 1,012 stars; Ptolemy, with a keener sight, counted 1,026; while Herschel, with his mighty glass, counted twenty millions. Yet I believe it was the high purpose of Hipparchus two hundred years before the Star of Bethlehem appeared in the blue firmanent that at last in the seventeenth century produced the first telescope in the hand of Galileo. Owen Meredith has beautifully said:

> Not a truth has to Art or to Science been given,
> But brows have ached over it and souls toiled and striven;
> And many have striven, and many have failed,
> And many died, slain by the truth they assailed.

The work of this Association has elevated and illuminated the work of our civilization for fifty-one years throughout our land, and nowhere, as Dr. Holland has said, more than right here in Pittsburg; and yet your labors are not confined to America only. You are in harmony with men who seek the truth in other lands and nowhere more than in that mother country, England, where the King lies in pain and peril. The mother sorrows and the great daughter in the West yearns with keenest sympathy while she

awaits the final word, trusting that the able and generous monarch may be preserved to further usefulness and honor in the service of his country.

Then into the fellowship of this imperial city and to this Institute, from our heart of hearts, we bid you thrice welcome. You are brothers of all true men here, for there is a kinship in the work of the human intellect which binds men indissolubly together in spite of intervening oceans and continents, the confusion of tongues and the flight of time. I bid you welcome. (Applause.)

Col. Geo. H. Anderson then spoke as follows:

Ladies and Gentlemen of the American Association for the Advancement of Science: I esteem it a great honor indeed, while I feel my own inadequacy, to present the congratulations of the people of Pittsburg such as you certainly deserve. Although my friend, Dr. Holland, has almost exhausted the subject, I thought I would trust myself to give you a few facts in regard to the greatness of Pittsburg, so that in your journeyings about the city you may see for yourselves some of the things which have been stated from this platform.

The other speakers have given you a beautiful and polished speech. However, there is always a last word, and I will just remind my friend, Mr. Holland, that he forgot one thing. He spoke for the Recorders of Pittsburg and Allegheny, but he neglected to tell you that both these gentlemen have said they would suspend all the laws of the city while this Association is in session which might interfere with your pleasure in any sense of the word. I am sure Dr. Holland will excuse me for reminding him of the omission.

You will see that I am rather youthful to reminisce back even one generation, but my recollection clearly goes back to the time when we were not a very great country, and when this city was rather a small, smoky place, the butt of jokes. One gentleman said he passed through Pittsburg and it looked to him like an iron pot with the lid off.

In 1820 the city of Pittsburg had a very small population, a few factories and furnaces, and the Ohio river carried the products west. Our country at that time was a poor, weak, country; we were in debt, for the first one hundred years of our existence, to the older countries of Europe. We needed supplies, and all the notes we could get discounted we carried to Europe to pay for the goods, and the result was we spent a good deal more than we made, and the inevitable result was bankruptcy, every ten years or so. But we would start anew—we are a hopeful people—and to-day, to the astonishment of everybody, where it was our ambition to send at least as much out as to pay for what we brought in the exports of this country exceed by over two million dollars

every day what is brought in, and in consequence of that we are not only saved from debt, but are ourselves becoming the money centres of the world, and the old countries are looking on in amazement and dread. And Pittsburg itself, with its little population in 1820, just about equalled by the half dozen small cities in this neighborhood, many of them having apparently all of the natural advantages of this city, has gone ahead of them. They have scarcely grown at all, while Pittsburg to-day, if all put together, would have a population of over 700,000 people, and with a history unsurpassed. Now, we cannot account for everything. Even these gentlemen who understand science will tell you that there is a jumping-off place somewhere. But these little cities have made comparatively small growth; they have done their best, and so have we.

Now, about Pittsburg: Early in this century Henry Clay, a wise, far-seeing statesman, was asked to vote for an appropriation for the improvement of the Ohio river so that the people could get their flat-boats up and down the river. And Mr. Clay said in his speech that he would not vote such an appropriation, for the reason that the Ohio river was an uncertain stream, one-half the time dried up and the rest of the year frozen up. And he defeated the bill. I speak of this incident because one of the great secrets of the prosperity of Pittsburg is found in her abundant transportation facilities. The Ohio river, to-day, from Pittsburg alone, handles twenty millions of tons of freight in the harbor of Pittsburg. The Monongahela river carried last year sixteen million tons of freight from Pittsburg; the Mississippi river fifteen millions of tons more. Now just imagine, if you can for an instant, the boom that is carried and the influence that is brought to bear upon the valleys of the Mississippi and the Ohio which carries our stuff to the markets of the world. Now, what had Science to do with this thing? Much. When Mr. Clay said that the river was dried up one-half the year and frozen up the rest of the time, he could not see into the future, but we know better now. We have a representative River Improvement Company, and scientific men have made possible the construction of the greatest river improvement apparatus in the world. We have opened clear river navigation; not a piece of timber or rock obstructs free navigation on our rivers. When it has fallen we create a great harbor; then the dam operates in the river and the stream is made serviceable. This system has been adopted by the U. S. Government, and they are using these movable dams, The most ingenious men we ever had in the days when Mr. Clay made his speech never dreamed of a river improvement movement like this. So much for science in the improvement of the Ohio river.

This little city, as I told you, has become a pretty big city now,

and I tell you that if we were all consolidated we would be, almost beyond computation, the greatest producing centre in the world, and if there is no check to the progress of the industrial plans of the city of Pittsburg in the next ten or twenty years she will be the centre of an unbroken chain of nearly one hundred miles of colossal plants. And we rejoice that it is so, for a thousand reasons, because we contribute to the wealth of this great country, and it has built up a wealth for the men who operate these establishments and have brought them to perfection. And you will see a good deal of this for yourself. A year ago we were favored, as we often are, by a distinguished visit. This gives us intense pleasure, outside of any personal or selfish consideration, to extend our hospitality in the most cordial way to all who visit us. Last fall the United States Government sent its Congressional Commission here to consult in regard to canals. To the gentlemen of that Commission we stated a number of things, and Dr. Johnson of the Commission suggested that we make a written report and that we confine ourselves strictly to facts. We were surprised at this and I said, "Why do you specially request us to stick to facts?" "Well," he said, "didn't you tell us that the tonnage was sixty-five million tons?" I said, "Yes." "Well," he said, "you are clearly in error as to that, because that is four times the tonnage of Chicago!" "Well," I said, "that is precisely what we mean." 2,500,000 freigght cars carried the tonnage of Pittsburg last year. It is almost incredible, but, Mr. Chairman, the next day we took those gentlemen up and down the river, and when they saw the line of industries forty or fifty miles long, and when one concern told us a few figures, he said, "I am done with the freight question. If one concern can handle sixteen million tons, this unbroken line of works will certainly do the rest."

I only wish to say how much we are gratified, on behalf of the great industrial interests, to meet this distinguished body of men, and all the more so, Mr. Chairman, because we know that the institution we represent, the themes that are published, the great amount of knowledge that is disseminated, by the body you represent, are things which have made Pittsburg great. Our labor and industry, reinforced by science, have made it possible for Pittsburg to reach its eminence to-day. If we had no other reason we could not do more nor less than to extend the most hearty welcome to you and say that the doors are wide open, and we bid you a hearty welcome to enter in and enjoy our city to its utmost.

In replying to the speeches of Dr. Holland and other representatives of the local committee, President Hall said:

The American Association for the Advancement of Science comes to hold its summer meeting in your city. It is fortunate for us to meet in the city of Pittsburg, famous for its wonderful

production of iron and steel, materials which lie at the foundation of modern civilization. We are glad to see the homes of men who are the munificent benefactors of our libraries and of our scientific institutions. We shall be interested in visiting the great shops where you convert the products of a generous nature into articles for our daily use.

Our Association was founded for the encouragement and diffusion of scientific learning. Its creed is very simple. It requires in the novice only will and devotion. It is our business to study the works of nature by observation and experiment, and it is our duty to conform our conduct to her laws. We invite all to join us in this work, for we believe that along this line of investigation lies the true road of progress for the human family. But we are free. We do not wish to impose our ideas on others, but prefer to leave them to the operations of reason and judgment. If a brother goes astray, and tries to square the circle, there is no trial for heresy. We let him alone, feeling sure that time, the implacable enemy of error, will lead him back to the truth. Cicero tells us that time overthrows the opinions of men, and confirms the decisions of nature. With full confidence in this sentiment we go on in our work, "without haste, and without rest."

A lecture on "The Prevention of the Pollution of Streams by Modern Methods of Sewage Treatment," by Dr. Leonard P. Kinnicutt, was given in the Music Hall, Carnegie Institute, on Monday evening, June 30, and the address of the retiring President, Dr. C. S. Minot, was delivered in the same place on the following evening. Mr. Robert T. Hill, of the U. S. Geological Survey, gave an illustrated lecture on "The Recent Disaster in Martinique" in the same place, on Thursday evening, July 3, which formed the concluding exercise of the meeting.

In order to facilitate business and shorten the period of necessary attendance of certain members of the Council, it was voted by that body that its duties be delegated to an executive committee consisting of the Secretaries of the Association and the Secretaries of the several Sections for the session of the Saturday preceding the week of the meeting in which the program is offered.

The Permanent Secretary was instructed to express to the Secretary of the Smithsonian Institution the appreciation of the Association for his services to science in providing for a table at the Naples Biological Station.

The Washington Committee on the election of new members during the interim of Council meetings was continued with power.

A message of sympathy was sent to King Edward of England.

Reports to Section A, by Alexander Macfarlane on quaternions, and by H. B. Newson on the theory of collineations, were ordered printed in full in the proceedings. The following resolu-

tions on the American International Archeological Commission. recommended by Section H, were approved and adopted by the Council and ordered printed:

WHEREAS, The Second International American Conference, commonly known as the Pan-American Congress, in session duly assembled in the City of Mexico, January 29, 1902, adopted a recommendation to the several American nations participating in the Conference, that an "American International Archeological Commission" be created;

WHEREAS, The recommendation has been transmitted by the President of the United States to the Congress (Senate Document No. 330 of the 57th Congress, 1st Session), thereby giving the project official status in the United States; and,

WHEREAS, The recommendation is in full accord with the spirit and objects of American science while international agreement in laws relating to antiquities is desirable; therefore

Resolved, That the American Association for the Advancement of Science heartily concurs in the recommendation of the Second International American Conference.

Resolved further, That the Secretary of the Association send a copy of this Resolution to the Director of the Bureau of American Republics, as an expression of the judgment of the Association.

Adopted by Section H on this July 2, 1902, and recommended to the Council for adoption on behalf of the Association.

STEWART CULIN,
Chairman,
HARLAN I. SMITH,
Secretary.

Reports of Standing Committees were presented and ordered printed as below:

TWENTIETH ANNUAL REPORT OF THE COMMITTEE ON INDEXING CHEMICAL LITERATURE.

The Committee on Indexing Chemical Literature, appointed by your body in 1882, respectfully presents to the Chemical Section its Twentieth Annual Report, covering the ten months ending June 1, 1902.

WORKS PUBLISHED.

A Bibliography of the Analytical Chemistry of Manganese, 1785–1900. BY HENRY P. TALBOT and JOHN W. BROWN. City of Washington, published by the Smithsonian Institution, 1902. 8°. viii + 124 pp. Smithsonian Miscellaneous Collections, Vol. XLI. (Number 1313.)

Index to the literature of the Spectroscope (1887–1900, both dates inclusive), [continuation of the previous index by the same author published in 1888.] By Alfred Tuckerman. Washington City, published by the Smithsonian Institution, 1902. 8°. iii + 373 pp. Smithsonian Miscellaneous Collections, Vol. XLI. (Number 1312.)

Chemical Societies of the Nineteenth Century. By Henry Carrington Bolton. City of Washington, published by the Smithsonian Institution, 1902. 8°. 15 pp. Smithsonian Miscellaneous Collections, Vol. XLI. (Number 1314.)

This contains a list of the serials published by the Societies, fifty-six in number, statistics of membership for 1900, titles of periodicals, etc.

On a System of Indexing Chemical Literature, adopted by the Classification Division of the U. S. Patent Office. By Edwin A. Hill. *J. Am. Chem. Soc.*, XXII, No. 8; also *Chem. News*, Vol. 84, 202, *et seq.* Oct.–Nov., 1901.

A Bibliography of Photography, by Miss Adelaide M. Chase, was begun in the February number of the *Photo Era*, published at Boston. It is confined to literature in English and does not include articles in photographic and chemical journals.

NOTES OF FOREIGN BIBLIOGRAPHIES.

Krupsky, A. K. Russkaya chast Khimicheskoy Bibliographii. S. Peterburg. 1900. 62 pp. 4to.

This is a reprint by the Imperial Academy of Sciences, St. Petersburg, of the Russian titles in Bolton's Select Bibliography of Chemistry. (Vols. 1–3.)

W. R. Whitney and J. E. Ober. Index to the Literature of Colloids. *J. Am. Chem. Soc.*, Vol. XXIII, pp. 842. (Nov., 1901.)

Glinzer, Langfurth und Voigtländer. Sammelkatalog der in Hamburger öffentlichen Bibliotheken vorhandenen Litteratur aus der Chemie und aus verwandten Wissenschaften. Hamburg, 1901. 108 pp. 8vo.

Garçon Jules. Répertoire général ou Dictionnaire méthodique de bibliographie des industries tinctoriales et des industries annexes. Paris, 1900–1901. 3 vols., roy. 8vo. 1978 pages in the 3 volumes.

This completes the work noticed in the Eighteenth Annual Report.

WORKS IN PROGRESS.

The MS. of an "Index to the Literature of Thorium," by Cavalier H. Joüet, Ph. D., of Columbia University, New York, has been examined by each member of your committee, and recommended for publication to the Smithsonian Institution. It is now being prepared for printing.

Mr. Benton Dales, of Cornell University, has in preparation "An Index to the Literature of the Yttrium Group of the Rare Earths."

Reports of progress have been received from Messrs. Frank R. Fraprie and H. Carrington Bolton.

It is the sad duty of the committee to record the death of one of its original members, Professor Albert R. Leeds, Ph.D., long Professor of Chemistry in the Stevens Institute of Technology, Hoboken, N. J. His contributions to chemical bibliography include "Indexes to the Literature of Ozone," and of "Peroxid of Hydrogen."

It is gratifying to note the increasing and continued interest in bibliography on all sides, and the committee stands ready to encourage the movement in chemistry by practical assistance to those desirous of contributing to the now considerable list of indexes. Address correspondence to the Chairman, at the Cosmos Club, Washington, D. C.

H. Carrington Bolton (in Europe),
F. W. Clarke,
A. B. Prescott,
Alfred Tuckerman,
H. W. Wiley,
Committee.

APPENDIX.

Bibliographies Named in Reports I–XX, 1883–1902.

The following list includes only those bibliographies that have been published under the auspices of the committee, or independently, as monographs and separates.

Copies may be obtained, so far as available, on application to the Society or Institution issuing them, or in some cases by addressing the authors.

Aceto-Acetic Ester, Bibliography of. By Paul H. Seymour. Smithsonian Miscellaneous Collections, No. 970. Washington, 1894. 8vo.

Carbides, Review and Bibliography of the Metallic. By J. A. Mathews. Smithsonian Miscellaneous Collections, No. 1090. City of Washington, 1898. pp. 32. 8vo.

Cerium and Lanthanum, Indexes to the Literature of. By W. H. Magee. Smithsonian Miscellaneous Collections, No. 971. Washington, 1895. pp. 43. 8vo.

Chemistry, A Select Bibliography of, 1492–1892. By Henry Carrington Bolton. Smithsonian Miscellaneous Collections, No. 850. Washington, 1893. pp. 1212. 8vo.

First Supplement, S. M. C., No. 1170, 1899.

Section VIII, *Academic Dissertations*, S. M C., No. 1253. 1901.

Columbium, Index to the Literature of, 1801–1887. By Frank W. Traphagen. Smithsonian Miscellaneous Collections, No. 663. Washington, 1888. pp. IV + 27. 8vo.

Didymium, Index to the Literature of, 1842–1893. By A. C. Langmuir. Smithsonian Miscellaneous Collections, No. 972. Washington, 1895. pp. 20. 8vo.

Explosives, Index to the Literature of, Part I. By Charles E. Munroe, Baltimore, 1886. pp. 42. 8vo.

Part II, Baltimore, 1893. pp. 43–195. 8vo.

Electrolysis, Index to the Literature of, 1784–1880. By W. Walter Webb. Annals of New York Academy of Sciences, Vol. II, No. 10, 1882. pp. 44. 8vo.

N. B. This has been translated into French by Donato Tommasi, Paris, 1889.

Heat, Dictionary of the Action of Heat upon certain Metallic Salts, including an Index to the principal literature upon the Subject. Compiled and arranged by J. W. Baird; contributed by A. B. Prescott, New York, 1884. pp. 70. 8vo.

Light, Chemical Influence of, A Bibliography of. Alfred Tuckerman. Smithsonian Miscellaneous Collections, No. 785. Washington, 1891. pp. 22. 8vo.

Manganese, Index to the Literature of, 1596–1874. By H. Carrington Bolton. Annals of the Lyceum of Natural History, New York. Vol. XI, November, 1875. pp. 44. 8vo.

Manganese, Analytical Chemistry of, A Bibliography of the. By Henry P. Talbot and John W. Brown. Smithsonian Miscellaneous Collections, No. 1313. City of Washington, 1902. pp., 8vo.

Morphine, Chemical Bibliography of, 1875–1897. By H. Brown. Pharmaceutical Archives. Vol. I, No. 3. No date, no place. pp. 60. 8vo.

Ozone, Index to the Literature of, 1785–1879. By Albert R. Leeds. Annals of the New York Academy of Sciences. Vol. I, No. 12, 1880. pp. 32. 8vo.

Ozone, Index to the Literature of, 1879–1883. Accompanied by an Historical Critical Résumé of the Progress of Discovery since 1879. By Albert R. Leeds. Annals N. Y. Academy of Sciences. Vol. III, pp. 137. 1884. pp. 16. 8vo.

Peroxid of Hydrogen, Index to the Literature of, 1818–1878. By Albert R. Leeds. Annals of the New York Academy of Sciences. Vol. I, No. 13, 1880. pp. 11. 8vo.

Peroxid of Hydrogen, Index to the Literature of, 1879–1883. By Albert R. Leeds. Annals of New York Academy of Sciences. Vol. III, pp. 153, 1884. pp. 3. 8vo.

Platinum Group, A Bibliography of the Metals of the. Platinum, Palladium, Iridium, Rhodium, Osmium, Ruthenium, 1748–1896. By James Lewis Howe. Smithsonian Miscellaneous Collections, No. 1084. City of Washington, 1897. pp. 318. 8vo.

Spectroscope, Index to the Literature of. By Alfred Tuckerman. Smithsonian Miscellaneous Collections, No. 658. Washington, 1888. pp. x + 423. 8vo.
The same, 1887–1900, both dates inclusive. S. M. C., No. 1312. Washington City, 1902. pp. iii + 373. 8vo.

Starch-sugar, Bibliography of. By Edward J. Hallock. Appendix E to Report on Glucose prepared by the National Academy of Sciences, in response to a request made by the Commissioner of Internal Revenue, U. S. Internal Revenue, Washington, D. C. 1884. pp. 44. 8vo.

Tannins, Index to the Literature of. By Henry Trimble. The Tannins. Philadelphia, 1892. Vol. I, Appendix. Vol. II, Philadelphia, 1894.

Thallium, Index to the Literature of. By Martha Doan. Smithsonian Miscellaneous Collections, Vol. XLI, No. 1171. Washington, 1899. pp. 26.

Thermodynamics, Index to the Literature of. By Alfred Tuckerman. Smithsonian Miscellaneous Collections, No. 741. Washington, 1890. pp. VI + 329. 8vo.

Thorium, Index to the Literature of. By Cavalier H. Jouet. Smithsonian Miscellaneous Collections, No. —. [In press.]

Titanium, Index to the Literature of, 1783–1876. By Edw. J. Hallock. Annals of the New York Academy of Sciences. Vol. 1, Nos. 2 and 3, 1877. pp. 22. 8vo.

Uranium, an Index to the Literature of, 1789–1885. By H. Carrington Bolton. Smithsonian Report for 1885. Washington, 1885. pp. 36. 8vo.

Vanadium, Index to the Literature of. By G. Jewett Rockwell. Annals of the New York Academy of Sciences, Vol. 1, No. 5, 1877. pp. 32. 8vo.

Zirconium, Index to the Literature of. By A. C. Langmuir and Charles Baskerville. Smithsonian Miscellaneous Collections, No. 1173. City of Washington, 1899. 29 pp. 8vo.

Report of the Committee on the Teaching of Anthropology in America.

To the Council of the American Association for the Advancement of Science.

The Committee on the Teaching of Anthropology in America beg to report a continuation of correspondence and conferences in the interests of Anthropological teaching. Some of the results of the correspondence are incorporated in a paper by one of the Committee (Dr. MacCurdy) entitled "The Teaching of Anthropology in the United States," published in SCIENCE, January, 1902. During the year a course of lectures was delivered by one of the Committee (the Chairman) in the Free Museum attached to the University of Pennsylvania, pursuant to the purposes of the Committee.

The expenses of the Committee have been inconsiderable and no appropriation was asked. It is recommended that the Committee be continued.

W J McGEE,
FRANZ BOAS,
W. H. HOLMES.

Report of the Committee on Anthropometry.

Anthropometric researches under the auspices of this Committee have been continued during the year. Professors Cattell and Boas, members of the Committee, and Professors Thorndike and Farrand, Fellows of the Association, have during the year made measurements of students entering and graduating from Columbia College, and have made other studies on individual differences. Professor Thorndike has investigated especially the correlation of traits in school children. Mr. Farrington has studied the question as to whether brothers who have attended Columbia University are more alike than those who are not brothers. Mr. Bair and Dr. Wissler are calculating the results of measurements of school children made by Professor Boas. Professor Cattell is collecting data on individual differences, in which 1,000 students of Columbia University, 1,000 of the most eminent men in history and 1,000 scientific men of the United States are being considered.

Progress has been made with the construction of a traveling set of anthropometric instruments, toward which an appropriation of $50 was made at the Denver meeting of the Association. It is believed that the model of a portable set of instruments would be of value for work in schools, for the study of primitive races, etc. The present set is the property of the Association and is to be used in the first instance in making physical and mental measurements of members. Such measurements were begun at the New York meeting, but they cannot be continued until a portable set of instruments is available and arrangements are made for assistance in carrying out the measurements. The instruments will be ready at the time of the Washington meeting, and an assistant could probably be secured to take the measurements if his traveling expenses were paid. We should be pleased if an appropriation to this Committee of $25 or $50 could be made for this purpose. An appropriation was made for a series of years by the British Association for its anthropometric laboratory. Our own measurements are more extended than those of the British Association, especially in the direction of mental traits; but it would be interesting to compare the measurements of the members of the British Association with similar measurements of American men of science.

J. McK. Cattell,
W J McGee,
Franz Boas.

Report of the Committee on the Study of Blind Invertebrates.

To the Council of the American Association for the Advancement of Science.

Gentlemen:

In behalf of your Committee on the Investigation of cave animals, I beg leave to report that the following publications have recently been issued, or will appear before the Washington meeting in January:

1. An account of the anthropods of the caves of Texas, by Carl Jost Ulrich, *Proc. Am. Micr. Society.*

2. An account of the history of the eye of amblyopsis from its appearance to death of the individual by old age.

3. The eyes of Rhineura, *Proc. Washington Acad. Sci.*

During March of the present year, the writer, accompanied by Mr. Oscar Riddle as assistant and interpreter, visited the blind fish caves of western Cuba. A general account of the trip was presented before Section F. The crustacea collected will be described by Mr. W. P. Hay. The eyes of the blind crustaceans and the eyes of the blind fishes, blind lizards, and blind snakes collected will be described by my students and myself.

The expenses of the Cuban trip, amounting to about $400, have been met in part by an unexpended balance of about $80 from the $150 heretofore granted by the A. A. A. S., a promise of $85 for a report on the fishes by the U. S. Fish Commission, and from the sale of specimens. In behalf of the Committee I respectfully request that the Committee be continued and that a grant of $100 be made to continue the work.

In the absence of the other members of the Committee respectfully submitted by

Carl H. Eigenmann,
Secretary

Report of the Committee on the Relations of Plants to Climate.

To the Members of the Council.

Gentlemen:

The efforts of the Committee have been directed to the development of methods which would secure continuous records of the temperature of the soil, and which would make possible an analysis of the comparative influence of the widely different soil and air temperatures upon the general development, physiology and distribution of plants. The Committee has been so fortunate as to secure the co-operation and interest of Professor Wm. Hallock,

of Columbia University, and a thermograph designed by him has been constructed and installed for taking continuous records of soil temperatures. (For description, see *Journal New York Botanical Garden*, July, 1902.) With the invention of this instrument, the Committee now finds itself in a position to study some of the main problems confronting it with much promise of success in the way of valuable results, and asks a further grant of sixty-five dollars to enable it to construct and maintain two additional instruments, and to make other necessary records and experiments. In the absence of the other members of the Committee, Messrs. Trelease and Coulter, this report is submitted with their general approval and with the unanimous approval of Section G.

Respectfully,

D. T. MacDougal.

Report of the Committee on the Atomic Weight of Thorium.

At the Denver meeting the sum of fifty dollars was granted to Charles Baskerville for researches on the Atomic Weight of Thorium. Mr. Baskerville, in working in conjunction with an assistant, Mr. R. O. E. Davis, has prepared two kilograms of very pure Thorium compound. Preliminary work on some of the old methods and a new method for the determination of the Atomic Weight of that element has been done, but sufficient results have not been accumulated to warrant publication. The Committee therefore desires to report progress, and respectfully request a continuation of the grant by the sum of fifty dollars for the current year. The grant was utilized for the purchase of a novel constant high temperature bath.

Respectfully submitted,

Charles Baskerville, *Chairman*,
F. P. Venable,
Jas. Lewis Howe.

The following grants were made for the ensuing year:

To the committee on anthropometric measurements - - - - . - - - - -	$50.00
To the committee on the investigation of blind invertebrates - - - - - - -	75.00
To the committee on the atomic weight of thorium	50.00
To the committee on the relations of plants to climate - - - - -- - - -	75.00

By the action of the Council on July 3, 1902, a new Committee, consisting of W. S. Franklin, D. B. Brace and E. F. Nichols, was appointed to which was entrusted investigations of the velocity of light, and a grant of $75.00 was made to this Committee.

At the sessions of the Council, held July 2 and 3, eighty members were elected Fellows.

As a result of action taken by the Council, Section D and the General Session on July 3, 1902, Mr. George Westinghouse was elected an Honorary Fellow of the Association.

The chief feature of the closing session of the Association in the Music Hall of the Carnegie Institute on Thursday evening, July 3, was an illustrated lecture by Mr. Robert T. Hill on the recent volcanic eruption in Martinique, in which his recent investigations were described. After the lecture a series of resolutions were passed expressing the thanks of the Association to the various persons and organizations in Pittsburg concerned in the organization of the meetings and entertainment of the members.

D. T. MacDougal,
General Secretary, A. A. A. S.

Report of the Treasurer.

In compliance with Article 15 of the Constitution, and by direction of the Council, I have the honor to submit the following report, showing receipts, disbursements, and disposition of funds of the Association for the year ending December 31, 1901.

Receipts have come into the keeping of the Treasurer from three sources, namely: First, from commutations of annual fees of life members of the Association; secondly, from excess of receipts over expenditures of the Permanent Secretary; and, thirdly, from interests on funds deposited in savings banks. The aggregate of these receipts is $2,397.89.

Disbursements made in accordance with the direction of the Council amount to $460.00.

The total amount of funds of the Association deposited in banks and subject to the order of the Treasurer, December 31, 1901, is $12,127.07.

The details of receipts, disbursements, and disposition of funds are shown in the following itemized statement.

Dated June 1, 1902.

THE TREASURER IN ACCOUNT WITH THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

1901.	DR.		
	To balance from last account - -		$10.189.18
Dec. 7.	To amount transferred from funds of Permanent Secretary - - - - -		1,000.00
Dec. 14.	To amount received for 21 life memberships		1,150.00
Dec. 31.	To amount received as interest on funds deposited in Savings Bank as follows:		
	From Cambridge Savings Bank, Cambridge, Mass. - - - -	$36.96	
	From Emigrant Industrial Savings Bank, New York, N. Y. - -	102.08	
	From Institution for the Savings of Merchants' Clerks, New York, N. Y.	99.50	
	From Metropolitan Savings Bank, New York, N. Y. - - - -	109.35	
	- - - -		347.89
l.	Total - - - - - -		$12,587.07

THE TREASURER IN ACCOUNT WITH THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

1901.	CR.		
Apr. 30.	By amount paid to Permanent Secretary from contribution of Mrs. Phœbe Thorne to New York Committee		$200.00
Aug. 29.	By cash paid D. T. MacDougal of committee on study of relations of plants to climate		60.00
Aug. 29.	By cash paid Jas. McK. Cattell of committee on anthropometric investigations		50.00
Oct. 4.	By cash paid Charles B. Davenport of committee on the study of biological variations		100.00
Nov. 11.	By cash paid Charles Baskerville of committee on the study of the atomic weight of thorium		50.00
Nov. 31.	By cash on deposit in banks as follows:		
	In Cambridge Savings Bank, Cambridge, Mass.	$1,084.32	
	In Immigrant Industrial Savings Bank, New York, N. Y.	2,882.93	
	In Institution for the Savings of Merchants' Clerks, New York, N. Y.	2,918.47	
	In Metropolitan Savings Bank, New York, N. Y.	2,999.15	
	In The Fifth Avenue Bank, New York, N. Y.	2,242.20	
			12,127.07
	Total		$12,587.07

I have examined the foregoing account and certify that it is correctly cast and properly vouched.

EMORY MCCLINTOCK,
Auditor.

JUNE 23, 1902.

Report of the Permanent Secretary.

The fifty-second annual meeting of the American Association for the Advancement of Science, now drawing to its close, will be known as the first Pittsburg meeting. In many respects it has been one of the most successful meetings which the Association has ever held. The attendance, while not very large, has been composed of members of the active working class, many of them being Fellows, and the meeting may be safely characterized as a working meeting. The registration has shown four hundred and thirty-five members in attendance. This ranks the Pittsburg meeting as the twelfth in size of the fifty-two meetings which have been held. It is the fourth in size of the meetings held during the past ten years. The geographic distribution of members in attendance is especially interesting, and those who have had the interest or curiosity to follow this matter of geographic distribution during recent years will notice that this year there is a larger attendance from the South than in any previous year. The exact representation by States has been as follows: Pennsylvania naturally heads the list with 178; New York, 59; Ohio, 49; District of Columbia, 45; Massachusetts, 23; Illinois, 21; Michigan, 10; Indiana, 10; New Jersey and Maryland, 8 each; Missouri, Minnesota, Kansas, New Hampshire, North Carolina, and West Virginia, 6 each; Texas and Nebraska, 5 each; Arkansas and Connecticut, 4 each; Alabama, Delaware, Virginia, California, Kentucky and Canada, 3 each; Montana, 2; South Carolina, Georgia, Louisiana, South Dakota, North Dakota, Mississippi, Iowa, Colorado, and Maine, 1 each.

It must be remembered as usual that the number registered, namely, 435, includes only the active members and associates of the Association, and that as a matter of fact there are always a few members in attendance who are so characteristically forgetful of all things except scientific matters that they entirely fail to register. The number registered is only an indication of the size of the meeting. For example, eleven affiliated societies of a national scope have met with us and have swelled the gathering of scientific men in Pittsburg during the past week to approximately 750 individuals. The meeting has, therefore, been a scientific congress of great importance.

The papers which have been read before the Association proper and in joint session with the more closely affiliated societies have been numerous and of a high order. About three hundred and sixty papers have been thus presented, which is a great increase over the number read at the last meeting of the Association.

A number of important measures concerning the future of the

Association have been considered and amendments to the constitution have been adopted rendering the council more permanent n its membership and thus probably more efficient in its work, and also making the sectional committees so constituted as to render their greater efficiency a matter of practical certainty About sixty new members have been elected during the meeting and about eighty members have been made fellows.

Pittsburg and its vicinity have provided visiting points of great scientific interest, and the fact just stated, together with the great courtesy and hospitality of the local committee and the citizens of Pittsburg, have combined to make the meeting now coming to a close a memorable one in the annals of the Association.

The following is a comparative statement of the roll as printed in the New York and Denver volumes and in the present volume.

	New York.	*Denver.*	*Pittsburg.*
Surviving founders	3	3	3
Living patrons	2	2	2
Living honorary fellows	2	2	3
Fellows	862	1,054	1,074
Members	1,052	1,904	2,392
Totals	1,921	2,965	3,474
Honorary life fellows (founders) included in the above	3	3	3

L. O. HOWARD,
Permanent Secretary.

L. O. HOWARD, PERMANENT SECRETARY, IN
TION FOR THE ADVANCE-

From January 1, 1901, to

DR.

To balance from last account, - -		$4,741.46
Admission fees for 1900, - - -	$15.00	
Admission fees for 1901, - - -	5,765.00	
Annual dues for 1902, - - - -	5,034.00	
Annual dues for 1901, - - -	7,874.00	
Annual dues for previous years, - -	774.00	
Associate fees, - - - -	123.00	
Fellowship fees, - - - - -	398.00	
Life membership fees, - - -	1,050.00	
		21,033.00
Publications, - - - -	68.29	
Binding, - - - - -	23.66	
Interest, - - - - -	38.20	
Miscellaneous receipts, - - -	210.44	
		340.59
		$26,115.05

ACCOUNT WITH THE AMERICAN ASSOCIA-MENT OF SCIENCE.

December 31, 1901.

CR.

By publications.		
To publishers of Science,	$5,195.00	
Vol. 50,	1,353.07	
		$6,548.07
By expenses Denver meeting.		
To Secretaries of Sections	232.66	
Denver pamphlet,	326.25	
General expenses,	180.25	
		739.16
By expenses in propagandist work.		
To local committees,	463.33	
Postage,	700.00	
Printing,	315.97	
Extra clerical help,	183.60	
Express,	150.00	
Telegrams,	7.00	
		1,819.90
By general office expenses.		
Express,	301.60	
Postage,	183.00	
Office supplies, typewriter, etc.,	139.51	
Telegrams,	10.98	
		635.09
By salaries.		
Permanent Secretary,	1,250.00	
Assistant Secretary,	500.00	
Assistant Secretary,	250.00	
		2,000.00
By miscellaneous disbursements.		
To back volumes of proceedings,	16.75	
Overpaid dues returned,	15.50	
Misc. small expenses,	4.75	
To cash paid Treasurer,	2,050.00	
		2,087.00
By balance to new account,		12,285.83
		$26,115.05

I hereby certify that I have examined this account and that it is correctly cast and properly vouched for, and that the balance was on deposit in Washington banks as follows: Citizens National Bank (January 2, 1902), \$9,955.62; National Safe Deposit and Trust Co. (including interest credited January 1), \$1,274.85; American Security and Trust Co. (including interest credited January 6), \$1,055.36; in all \$12,285.83.

G. K. Gilbert, *Auditor.*

APPENDIX.

REPORT ON THE THEORY OF COLLINEATIONS.

BY HENRY B. NEWSON.

[Read before Section A of the A. A. A. S., Pittsburg Meeting, July 2, 1902. Manuscript received too late to be inserted in the proceedings of Section A.]

§ 1. INTRODUCTION.

There has grown up in recent years in Section A the happy custom of requiring each year of some worker in some fertile field of mathematical research that he report to this gathering on the harvests of the past year, on the conditions of the present crops, on the prospects of the future, on the rainfall, the sunshine, the floods, on the drouths—in short on all things affecting mathematical prosperity within the confines of his happy valley. We can all recall with pleasure several such stimulating reports in the years just passed, and we look forward to many such reports to be presented in the future. To-day I bring my contribution, such as it is, and beg your indulgence while I endeavor to report the experiences of a day laborer in the fields where we cultivate the theory of collineations.

Your committee first suggested a report on Lie's theory of continuous groups, but after careful consideration I declined the larger task and offered instead to treat the narrower theme of collineations and their groups. One reason for declining the larger task was the certain knowledge of my own inability to do justice to so large a field; a second reason is the well-known fact that the *Deutscher Mathematiker-Vereinigung*, through a committee composed of some of Lie's most favored pupils, is preparing a comprehensive report on Lie's work which will be more thorough, more accurate, and more appreciative than any I could hope to prepare.

I shall confine myself, therefore, to the theory of collinea-

tions and their continuous (or Lie) groups. The group of projective transformations, or collineations, is by far the most important of the continuous groups discovered by Lie and developed by him in his "*Theorie der Transformationsgruppen.*" This group lies at the very heart and core of his theory for the reason that all other continuous groups can, by a suitable transformation of variables, be shown to be similar in structure to some projective group. Therefore every contribution to our knowledge of collineations and their groups reacts upon the wider theory of all continuous groups. Hence there is ample justification for confining this sketch to the narrower theme of collineations and their groups, in so much as the wider is included in the narrower—a pleasing paradox.

§ 2. Definitions and Methods.

We shall deal throughout with the idea of a transformation entirely from the geometric point of view, and shall be but little concerned with the purely analytic point of view which is more often adopted. A transformation of the elements of a space is defined as an operation which interchanges among themselves the elements of a space, but leaves the space, considered as the aggregate of all its elements, unchanged as a whole. We are usually not concerned with the machinery of a transformation, but only with its effect. The operation may be produced by means of a mechanical device, an analytical formula, a geometrical construction, or in any other way. Sometimes there are several different methods of producing one and the same transformation; but the effect is the same no matter by what method produced.

We usually consider the point as the simplest space element; but our space may be considered as made up of other geometric elements, as for example, lines, planes, spheres, etc. A plane contains ∞^2 points, ∞^2 lines, ∞ lineal elements, ∞^3 circles, ∞^5 conics. The dimensions of a space depend upon the number of elements of a chosen kind which make up the space. Thus a plane is a space of two dimensions when it is considered as made up of points or lines; of three dimen-

sions when the elements are lineal elements or circles; of five dimensions when the elements are conics.

A transformation of space which transforms points into points is called a point transformation; this is the most common kind. If lines are transformed into lines, it is called a line transformation. When lineal elements of a plane are transformed into lineal elements, we have what is called a contact transformation of the plane. A collineation is defined as one that transforms points into points, lines into lines, and planes into planes. It is, therefore, a self-dualistic transformation.

A collineation may be regarded from two distinct points of view, viz., the analytic and the synthetic. From the synthetic point of view the phenomena of a transformation appeal directly to the eye or to the space intuitions. On the other hand from the analytic point of view the operation is seen through the medium of a linear substitution on the requisite number of variables. The two methods have long been in use side by side and each has its special advantages. Each also has its special votaries, and each will continue to have its advocates as long as human minds continue to be constructed on different patterns. To me the synthetic method is the more attractive for the reason that it enables one to get closer to the facts and to view them at first hand. In all applications of analysis to geometry a formula is only the vehicle which conveys the thought, not the thought itself. The inevitable tendency is to confuse the vehicle with the thought, to mistake the vessel for the contents, and to lay hold on the shadow rather than the substance of the thing sought.

§ 3. Different Methods.

I shall now pass in review some of the different methods which in times past and in times present have been used to add to our knowledge of collineations or to throw light upon their theory.

Des Carte's Analytical Geometry. The analytic theory of collineations is foreshadowed in the cartesian geometry. The

usual formula for the transformation of co-ordinates in plane analytics, viz.,

$$x_1 = ax + by + c$$
$$y_1 = a'x + b'y + c', \qquad (1)$$

is capable of a double interpretation; first, we may interpret this operation as one that leaves the plane and all of its elements unchanged, but takes for new axes of x and y the lines whose equations are respectively $ax + by + c = 0$ and $a'x + b'y + c' = 0$; secondly, we may regard the same operation as one which leaves the position of the axes of coördinates unchanged, but which shifts the points and lines of the plane so that the lines $ax + by + c = 0$ and $a'x + b'y + c' = 0$ are brought into the positions before occupied by the lines $x_1 = 0$ and $y_1 = 0$, respectively. In terms of the second interpretation our operation has produced a collineation of the plane—a special collineation, to be sure, in which the line at infinity has not changed its position. This second method of interpreting equations (1) is not so old as the first, but doubtless was perceived by some minds very early in the history of the science.

Möbius' Barycentrische Calcul. The concept and term collineation* were introduced into geometry, so far as I have been able to ascertain, by Möbius in his *Barycentrische Calcul* published at Leipzig in 1827. Chapters seven and eight of this classical work are devoted to the elucidation of the idea and the development of the properties of that particular relationship of figures known as a collineation. Möbius seems to have reached the idea of a collineation in its most general form as the result of a generalization from the simpler notions of equality, similarity, affinity and perspectivity of geometrical figures. According to his definition of a collineation points correspond to points and straight lines to straight lines, *i. e.*, coll near points to collinear points, whence the name.

We owe to Möb us not only the first clear cut notion of a collineation and its name, but also the fundamental theorem

*Möbius tells us in his *Vorrede*, p. xii, that the name was suggested to him by his friend, Professor Weiske.

underlying all his work on this subject, viz., that the cross ratios of four corresponding elements of two collinear figures are always equal. This, it seems to me, must be reckoned as the most important contribution of Möbius to the subject. He also gives us methods for constructing collineations on a line in a plane, and in space. He shows that three points on a line, four points in a plane, five points in ordinary space, in general $n - 2$ points in a space of n dimensions, determine a collineation in these spaces, respectively. He points out that two conics in a plane are always collinear to one another in ∞^3 ways; and that in two collinear systems of points a curve of the nth degree corresponds to a curve of the same degree. But we find no hint anywhere in Möbius' work that there are any self-corresponding points, lines, or planes in a collineation. This important phase of the subject was left for other investigators in this field.

Cayley and Sylvester's Invariant Theory. With the introduction of homogeneous coördinates into analytic geometry there came in a generalized form the old problems connected with the transformation of coördinate axes. Such a transformation is a linear transformation, and hence the theory of linear transformations came to be studied as a subsection of modern analytic geometry. A forward step in the theory of collineations was taken by the English school of mathematicians who founded the invariant theory of linear transformations. This theory took its rise shortly after 1840, and the principal names associated with its early development are those of Boole, Cayley, Sylvester, Salmon.*

A linear transformation on n variables is a purely algebraic operation, and in the minds of many mathematicians the invariant theory is a purely algebraic theory. But the geometric interpretation of a linear transformation on n variables is a collineation in space of $(n - 1)$ dimensions. Thus the algebraic invariant theory of homogeneous forms pointed the way to an analytic theory of collineations.

Since a linear transformation is a projective transformation, every theorem concerning linear transformations has its bear-

*See note to Salmon's Algebra, Chapter XIII.

ing on the theory of collineations. The workers in projective invariant theory who considered the geometric applications of their science looked more to the effect of a linear transformation on a geometric figure than to the properties of the transformation itself. Thus we look in vain through the standard works on invariant theory for a classification of linear transformations or a discussion of their characteristic properties. It was left to later times and to men with a different point of view to call the attention of the mathematical world from the effects of a collineation back to the properties of the collineation itself.

Lie's Theory of the Projective Group. About the year 1870 there appeared upon the mathematical stage a new personality, Sophus Lie, from the land of Abel. He brought with him a new and original idea, the notion of a continuous group of transformations. Lie broadened and deepened the already existing notions of a transformation, and developed a complete theory of all continuous groups of transformations, a thirty years' task. Among the many transformations studied by Lie the first, the simplest, the most centrally situated, and the most far-reaching in its theoretical and practical bearings, are projective transformations or collineations.

Lie's work on the theory of collineations was both synthetical and analytical; synthetical in its earliest conception and announcement, analytical in its final form as presented to the mathematical world in the books published in his later years. Lie throughout kept his eye fixed on the properties of the collineation itself rather than on the effect of the collineation on certain configurations of space. But it is evident to every careful student of Lie's theory that his chief interest in projective transformations was in their group properties, and not in those more fundamental properties which form the natural basis for a classification both of collineations and their groups.

But after all is said the most important and most interesting properties of collineations are their group properties; and no discussion of the theory of collineations is full and symmetrical which fails to lay the major stress on the considera-

tion of the collineation groups. Lie 's work will never be forgotten; the foundations of his theory of projective groups are laid on the eternal rocks of truth; yet his is by no means the final word on this subject. His results, barring a few errors, will stand, but many of his methods will probably be discarded for others more direct and incisive. In the next section I shall endeavor to show wherein Lie's methods fall short of telling us the whole truth.

Grassmann's Ausdehungslehre. In 1844 Hermann Grassmann published his Ausdehungslehre, or Calculus of Extension. A second edition, or rather a second presentation of the same subject, was published by him in 1862. The method of the Calculus of Extension was not applied directly by Grassmann to the theory of collineations, but it is capable of application to some phases of the subject. For example, by this method the various types of collineations in ordinary space have been determined. On this point see the reference in the next section. Although the contributions of Grassmann's theory to the theory of collineations have been relatively small, they are sufficient to warrant the mention of this method among the analytic methods of treating collineations.

Hamilton's Quaternion Calculus. The quaternion calculus invented by Sir William R. Hamilton, and published by him in his Lectures on Quaternions in 1844, is an algebra founded on a complex number system of four units. It has been successfully applied by its founder and his followers to many problems in geometry and physics. One of its valuable applications is to the theory of homogeneous strains. A homogeneous strain is by definition a collineation in ordinary space; a very special kind of collineation to be sure, viz., one which leaves the plane at infinity invariant, but nevertheless a true collineation. However, the quaternion calculus has not been extensively applied to the theory of collineations in ordinary space, probably because it has not been found to be a suitable instrument for the purpose.

Cayley's Theory of Matrices. We mention next an analytic method whose most natural and obvious geometrical

application is to the theory of collineations. I refer to Cayley's theory of matrices. This theory was set forth in his memoir on this subject in 1858. This subject has never become a popular one among mathematicians in the sense that it has attracted a large number of independent investigators. It did not lead its founder to the general theory of collineation groups, although it has contributed largely, through the labors of Frobenius and others, to some phases of group theory.

Von Staudt's Geometrie der Lage. All the mathematical theories so far mentioned bearing on the theory of collineations have been analytic methods. We have yet to mention the leading methods and names connected with the development of pure synthetic geometry. The thought calls up in every mind the names of Monge, Poncelet, Steiner, Charles, Von Staudt. These are the great names in projective geometry, and each is associated with a special phase of its development. I wish however, to call your attention in particular to one of these men, and his work. Whoever would acquire a knowledge of projective geometry in its purest and most rigorous form must spend his days and nights with Von Staudt. In his *Geometrie der Lage*, Nuremberg, 1847–60, Von Staudt laid the foundations of pure projective geometry in a form in, dependent of the assumptions of measurement, mechanics or congruence, and without quantitative notions of any sort. He distinguishes sharply between Geometrie der Lage and Geometrie des Masses. Pure projective geometry and the theory of collineations may be considered in a certain sense as mutually inclusive sciences. My conception of the distinction between them is expressed by saying that projective geometry deals chiefly with the projective properties of figures, while the theory of collineations considers especially the properties of the projection itself. Some of Von Staudt's contributions to the latter theory are given in the next section.

§ 4. Types of Collineations.

Every collineation in space of any number of dimensions has one or more self-corresponding points, lines or planes.

These self-corresponding elements make up the invariant figure of the collineation, and the fundamental properties of collineation which serve as a basis for a proper classification into types are dependent upon their invariant figures. In the past mathematicians were slow in recognizing the existence and importance of the different types of collineations, but in recent years they have received fuller recognition.

Von Staudt was the first, so far as I have been able to ascertain, to recognize and enumerate the various types of collineations in space of one, two, and three dimensions. Many others since his time have made the same enumeration by different methods and for different purposes. It is interesting to note the various solutions of this problem and the various methods employed. In his *Geometrie der Lage* of 1847, page 55, Von Staudt shows that a one-dimensional projective transformation leaves two elements invariant; the special case where these two elements coincide is not noted here. But in his *Beiträge zur Geometrie der Lage* of 1856, page 146, we find it explicitly stated that two projective ranges on the same base have one, two or all of these elements in common, *i. e.*, any one-dimensional collineation, not an identical collineation, has either one or two elements invariant. This fact has long since become a commonplace of projective geometry.

In regard to the various types of collineations in the plane, we find on page 187 of the same *Beiträge* that Von Staudt distinguishes between the perspective and the non-perspective collineations, and shows that the latter leave invariant, 1st, either three points and three lines forming a triangle; or 2d, two points and two lines through the two points; or 3d, one point and one line through it forming a lineal element. The perspective collineations of the plane are two in kind, *i. e.*, the vertex is either on or off the axis of the collineation. Von Staudt thus recognized in 1856 the five well-known types of plane collineations.

Four years later, in the third *Beiträge zur Geometrie der Lage*, § 35, we find the first enumeration and characterization of the thirteen types of collineations in space of three dimen-

sions. Each of these types is characterized by its invariant figure. The characteristic invariant figures of these different types are shown in the accompanying plates. Through the rest of his treatise Von Staudt makes but little explicit use of his discovery of these types. It is true they are not of great importance to him because of the nature of the problems with which he concerned himself; but for the theory of collineations of to-day they are of prime and ever increasing importance.

Von Staudt's determination of the various types of collineations was by pure synthetic methods. A pure analytic method was employed by Segre some years later to solve the same problem. Making use of Weierstrass' theory of the *Elementartheiler* of a determinant of a bilinear form, Segre in a paper in the *Rendiconti 'di Reale Academia dei Lincei, Tome* XIX, page 6, 1884, made a classification of the collineations in space of n dimensions. I have not been able to consult this paper, and have only seen the notice of it in the *Fortschritte der Mathematik*. The method and substance of Segre's paper are reproduced by Muth in his *Theorie und Anvendung der Elementartheiler*, §17, Leipzig, 1899. On pages 214–220 of his book, Muth determines the types of collineations in one, two, and three dimensions. His results agree with those obtained by Von Staudt. Muth gives full reference and credit to Segre.

Whitehead, in his Universal Algebra, Cambridge 1897, pp. 316–346, gives a chapter on Matrices and Forces which is devoted to linear transformations in three dimensions. By means of Cayley's theory of matrices the thirteen types of collineations in three dimensions are described and classified. according to the distribution of latent and semi-latent regions.

This same problem has also been solved by H. Grassmann, the younger, by means of the Calculus of Extension. His work is to be found in a note to §§ 377–390 of the *Ausdehungslehre* of 1862, Engel's Edition.

In Lie's *Vorlesungen ueber Continuierliche Gruppen*, Leipzig, 1893, pp. 65–67 and pp. 510–512, the five types of collineations in the plane are explicitly shown; but nowhere in

this work or in his *Theorie der Transformationsgruppen*, Leipzig, 1888–93, are the thirteen types of collineations in three dimensions enumerated or so much as referred to. This is certainly a strange omission on Lie's part, for it is not probable that he was at this time unfamiliar with the investigations of others on this question. However, in the *Leipziger Berichte* for March, 1895, on pages 210–211, Lie refers to a former paper of his in the Norwegian *Archives for Mathematik* for 1882, in which he has shown that the homogeneous transformations in three variables can be brought to fourteen canonical forms. These include the identical transformation and, I suppose, the remaining canonical forms correspond to the thirteen types of collineations in space—I say suppose for I have not been able to consult the original article. If my surmise is correct, then Lie was familiar with these thirteen types in 1882.

In a paper published in the Kansas University Quarterly, Vol.VI, pp. 63–70, 1897, the writer of this report also determined the types of collineations in space by a method different from any previously employed. His method rests on the fundamental principle that a collineation is a self-dualistic transformation and, hence, the invariant figure is a self-dualistic figure. It is easily shown that the most general invariant figure is a tetrahedron, which is evidently a self-dualistic figure. Only such modified forms of the tetrahedron as are self-dualistic can be invariant figures of the various special types of collineations. It follows without difficulty that there are twelve and only twelve such special forms; hence there are thirteen possible forms left invariant by a collineation, and corresponding to each is a type of collineation in space. At the time of the publication of this paper I was not aware that the problem had already been solved by Von Staudt and others.

§ 5. A Theory of Collineations.

I wish now to sketch in brief outline a geometric theory of collineations which is based directly upon the properties

of the various types of collineations in one, two, and three dimensions.

One Dimension. A one-dimensional collineation of points on a line, as stated above, leaves invariant in the most general case two points, A and B; and the cross ratio of any four points is equal to that of their four corresponding points. If (P, P_1), (Q, Q_1), (R, R_1), etc., are pairs of corresponding points then $(ABPQ) = (ABP_1Q_1)$ whence

$$\frac{AP}{BP} \cdot \frac{BQ}{AQ} = \frac{AP_1}{BP_1} \cdot \frac{BQ_1}{AQ_1} \therefore \frac{AP}{BP} \cdot \frac{BP_1}{AP_1} = \frac{AQ}{BQ} \cdot \frac{BQ_1}{AQ_1},$$

i. e., $(ABPP_1) = (ABQQ_1) = (ABRR_1) = k.$

Thus in a given collineation the cross ratio of the invariant points and a pair of corresponding points is a constant for all pairs of corresponding points. This cross ratio k is the characteristic constant of the collineation. A one-dimensional collineation of the points on a line, which has only one invariant point, is characterized by a constant that is not a cross ratio. This case in which the two invariant points coincide, may be regarded as a limiting case of the above. From $(ABPP_1) = k$ we get $(APBP_1) = 1 - k$; whence $\frac{PP_1}{PB \,.\, AP_1} = \frac{1-k}{AB}$. But $k = 1$, when $B = A$; hence, putting $\lim_{B=A} \frac{1-k}{AB} = a$, we have $\frac{1}{AP} - \frac{1}{AP} = a$. Here a is a constant which characterizes this kind of a collineation. Two such collineations with the same invariant point differ only in the value of a.

In the case of a one-dimensional transformation of a pencil of lines (or planes) the theory is the same as in the general case, except that we have the cross ratio of the sines of four angles instead of the cross ratio of four segments. Upon the foundations furnished by these very simple properties of one-dimensional transformations, and by making use of our knowledge of the various types of collineations in higher dimensions, it is possible to build up a simple, natural, and

comprehensive theory of collineations in the plane and higher spaces.

Two Dimensions. A collineation of type I in the plane leaves a triangle invariant. Along each side of the invariant triangle is a one-dimensional collineation with two invariant points. Each of these one-dimensional collineations is characterized by a cross ratio; but of these three cross ratios only two are independent. Let the invariant triangle be ABC, and let the cross ratios of the one-dimensional collineations along AB and AC be k and k', respectively. Two plane collineations with the same invariant triangle ABC differ only in the values of k and k'. All properties of a plane collineation of type I depend upon the position of the invariant triangle and the properties of the two independent one-dimensional collineations along two of its invariant lines.

A collineation of type II may be considered as the limiting case of type I when two of the invariant points of the latter coincide. In this case the invariant triangle reduces to the figure ABl, and instead of the cross ratio k' along l we have the constant a, where $a = \lim_{C=A} \frac{1-k'}{AC}$. Upon the two constants k and a and the position of the invariant figure depend all the properties of a collineation of type II.

In a similar manner it may be shown that a plane collineation of any other type is fully characterized by its invariant figure and one or more one-dimensional collineations along the invariant lines or through the invariant points of the invariant figure. The complete theory of plane collineations follows readily from the complete theory of one-dimensional collineations and a knowledge of the various types of collineations in the plane.

Three Dimensions. Passing now to the consideration of collineations in space of three dimensions, we have first of all the above mentioned thirteen types, each characterized by its invariant figure. Our theory of collineations in space rests upon a knowledge of these thirteen types, and of the one and two dimensional collineations along the invariant lines and in the invariant planes of the invariant figures of the

space collineation. We shall next illustrate this by two or three examples chosen from the thirteen types.

A collineation in space of type I leaves invariant a tetrahedron $(ABCD)$ consisting of four invariant points, four invariant planes, and six invariant lines. Along each of these invariant lines, the edges of the invariant tetrahedron, is a one-dimensional collineation with two invariant points, each collineation being characterized by a cross ratio. But of these six cross ratios only three are independent. We may take for the three independent ones those along the edges AB, AC, AD, meeting in A. Let these cross ratios be respectively k, k', k''. The position of the tetrahedron $(ABCD)$ and the values of these three cross ratios completely and fully determine all properties of a collineation of type I in space.

In a similar manner a space collineation of type II, leaving invariant the figure $(ABCl)$ is characterized by the constants k, k', a, which are the constants of the three one-dimensional collineations along AB, AC, and Al, respectively. The plane collineation in the invariant plane ABC of the space collineation is of type I, while in the invariant planes ABl and ACl they are of type II. Two space collineations of type II with the same invariant figure differ only in the values of these constants k, k', a.

Again a space collineation of type VI, whose invariant figure consists of two points, A and B, the line l joining them, all planes through l and all points on a line l' not intersecting l, is characterized by two independent cross ratios k and k'. The plane collineations in each invariant plane are all of type I and all exactly alike.

It is not necessary to examine in detail all of the thirteen types; it is sufficient to emphasize the fact that collineations of different types have very different properties, and that the properties of a collineation of any type are determined by its invariant figure and the characteristic constants of the one-dimensional collineations along certain of its invariant lines.

§ 6. Group Properties of Collineations.

The most important properties of collineations, and also those properties which in recent times have attracted most attention, are their group properties. Lie introduced into mathematics the idea of a continuous group of transformations, and his earliest examples were groups of collineations. All collineations in a space of any given number of dimensions form a group. Thus the effect produced on the elements of any space by two collineations acting in succession may also be produced by a single collineation. This may also be expressed by saying that the resultant of any two component collineations is a collineation. Every system of collineations having this property constitutes a group, and the investigation and classification of the various groups of collineations is one of the living problems of to-day.

Fundamental Groups. To every type of collineation in any number of dimensions belongs a certain group, called its fundamental group. This is composed of the totality of collineations of that type which leave invariant the characteristic invariant figure of that type. Thus in one dimension there is two fundamental groups, viz: $G_1\ (AA')$ and $G_1\ (A)$. The first is composed of all the collineations, necessarily of type I, which leave a pair of points invariant; and the second is composed of all collineations of type II which leave a single point invariant. The natural parameter of the group $G_1\ (AA')$ is the characteristic cross ratio k; that of the group $G_1\ (A)$ is the characteristic constant α. In the group $G_1\ (AA')$ the cross ratio of the resultant of two collineations equals the product of the cross ratios of the components; thus $k_2 = kk_1$. In the group $G_1\ (A)$ the constant of the resultant of two collineations equals the sum of the constants of the components; thus $\alpha = \alpha + \alpha_1$.

In the plane there are five fundamental groups of collineations, one for each type.

The invariant figure of a collineation of type I is a triangle ABC, and the aggregate of all collineations with the same invariant figure forms the fundamental group of type I. Two

such collineations differ only in the values of k and k'. This is a group of two parameters, viz., k and k'. The law of combination of parameters in this group is expressed by $k_2 = kk_1$, and $k'_2 = k'k'_1$: the symbol for the group is G_2 (ABC).

Leaving invariant the figure ABl there are ∞ collineations of type II, two of which differ only in the values of k and a. This system of collineations forms the two-parameter fundamental group G_2 (ABl), the parameters being k and a. The resultant of two collineations of this group whose constants are (k, a) and (k_1, a_1), respectively, has for its constants (k_2, a_2), where $k_2 = kk$, and $a_2 = a + a_1$.

In like manner each of the types III, IV, and V has its fundamental group; that of type III is a three-parameter group G_3 (Al), that of type IV is a one-parameter group G_1 (A, l), that of type V is a one-parameter group G_1 (Al).

Two illustrations of fundamental groups of collineations in space will suffice for the purposes of this paper, and we select types I and VII. A collineation of type I leaves invariant a tetrahedron $ABCD$, and is characterized by three cross ratios k, k', k''. Two collineations having the same invariant tetrahedron differ only in the values of these cross ratios. The system of ∞^3 collineations with the same invariant tetrahedron forms a continuous group of three parameters, viz., k, k', k''. The natural parameters of this fundamental group G_3 $(ABCD)$, obey the following laws of combination: $k_2 = kk_1$, $k'_2 = k'k'_1$, $k''_2 = k''k''_1$.

The invariant figure of type VII may be designated by All', where p is the invariant plane determined by the invariant point A and the line of invariant points l, and l' is an invariant line through A not in the plane p. A collineation of type VII leaving $Apll'$ invariant is determined by two constants, k, and a. a is the constant of the one-dimensional collineation along l, and k is the cross ratio along each of the invariant lines of the pencil through A in the plane p. Two collineations of type VII with the same invariant figure differ only in the values of k and a. The system of ∞ collineations of this type leaving $Apll'$ invariant form a two-parameter group G_2 $(Apll')$ the natural parameters being k and a. It

should be observed that all planes through the line l are invariant planes, and in each of them we have a two-parameter group of plane collineation of type II. The determination of the fundamental group for each of the other eleven types of collineations in space presents no special difficulty.

Sub-groups of Fundamental Groups. Each fundamental group which depends upon more than one parameter breaks up in a characteristic way into sub-groups. Thus, for example, the fundamental group $G_2\ (ABC)$ of type I in the plane breaks up into sub-groups in this way: The infinite system of collineations in $G_2\ (ABC)$ for which the two cross ratios k and k' satisfy the relation $k' = k^c$, where c is a constant, forms a one-parameter sub-group; the parameter is k and there is a sub-group for each value of c. As another example the fundamental group $G_2\ (Apll')$ of type VII in space breaks up into one-parameter sub-groups as follows: Take from $G_2\ (Apll')$ the infinite number of collineations for each of which the constants k and a satisfy the relation $k = a^a$, where a is a constant; these form a group $G_1\ (Apll)_a$ of one-parameter. Other examples of the sub-groups of fundamental groups might be added did time permit. Each example would require separate examination.

Composite Groups. Having determined the fundamental group and its sub-groups for each type of collineation in space of any number of dimensions, it becomes an easy task to build up all groups of higher orders from these groups already found. For example, let us consider the groups of higher order which can be built up out of the fundamental group G (ABC) of type I. We shall find that there are just eight figures in the plane which constitute the whole or a part of a triangle. These are the triangle ABC, the figure ABl composed of two points and two lines, the figure AB composed of two points and their joining line, the figure ll' composed of two lines and their point of intersection, the figure A, l composed of a point and line separate, a lineal element Al, a line l, and a point A. There is a composite group corresponding to each of these figures. They are designated by $G_2\ (ABC)$, $G_3\ (ABl)$, G_4 (AB), $G_4\ (ll)$, $G_4\ (A, l)$, $G_5\ (Al)$, $G_6\ (A)$, $G_6\ (l)$. To these

eight groups must be added the group G_8 of all collineations in the plane. These groups constitute a class by themselves and are called the groups of type I of the first class.

If time permitted it might be shown that five of these nine groups of the first class break up into sub-groups of the so-called second class, just as the group G_2 (ABC) breaks up into sub-groups G_1 $(ABC)_c$. These five groups of the second class are G_1 $(ABC)_c$, G_2 $(ABl)_c$, G_3 $(AB)_c$, G_3 $(ll)_c$, G_4 $(Al)_c$. The other four groups of the first class do not break up in this way into sub-groups, except for special values of c. These sub-groups which exist for special values of c constitute the third class of groups of type I.

In space of three dimensions the task of classifying the groups of any type is much greater because of the larger number of groups. Thus there are thirty-two figures in space which constitute the whole or some part of a tetrahedron; each of these is the invariant figure of a group of the first class of type I in space. There are thirteen types of collineations in space and each type has from one to five classes of groups; thus we see that the number of groups of collineations in space is very large. My own unpublished list of these groups, which is yet subject to revision, shows more than five hundred varieties against forty-four varieties in space of two dimensions.

§ 7. Some Recent American Work on Collineations.

It may not be out of place here to call your attention to some recent American work on the subject of collineations, including some of my own.

At Yale University Professor Smith and his pupils have successfully attacked the question of the resolution of collineations into simpler ones. Making use of a theorem of Wiener, that every displacement in ordinary space is the resultant of two line reflections (involutoric collineations of type X), simplified proofs have been given by Mr. Gale of several theorems of Chasles and others on the theory of displacements in euclidian space. Miss Ruth Wood has further shown that

every collineation of space that leaves a quadric surface invariant can be resolved into two involutoric skew-perspective collineations (of type X in my notation). She proves this for each of the six (not five) types of collineations contained in the group G_6 (F). Interpreting this result in terms of non-euclidian geometry, it is shown that every displacement in non-euclidian space is the resultant of two skew-perspective line reflections on conjugate polars of the absolute.

At Clark University Professor Taber and his pupils have interested themselves in the problem of singular transformations in otherwise continuous groups, *i. e.*, in those individual transformations which cannot be generated by a repetition of an infinitesimal transformation of the group. A flaw in Lie's proof of certain fundamental theorems has been pointed out, and the reason for the existence of singular transformations made clear from the analytic point of view. The application of these results to the collineation groups of the plane and space shows that many of these groups are continuous only in the neighborhood of the identical transformation. A discussion* on this same topic from the synthetic point of view has recently been given by the writer.

At the University of Chicago Professor Dickson has been developing the theory of the groups of linear transformations whose coefficients belong to a given Galois field. His methods and results hold also to a certain extent when the field is extended to the field of all complex numbers. In this case the groups which he discusses become continuous groups of collineations. Prof. Dickson's results are of wide generality and substantial contributions to the theory in n dimensions.

At the University of Kansas the writer and some of his pupils have been engaged in developing the theory of collineations outlined in the above pages. The *American Journal of Mathematics* for April last contains a memoir devoted to the application of this theory to the collineation groups of the plane. A similar investigation of the same problems for three dimensions is nearly completed. Three papers dealing with the fundamental groups and their sub-groups for types

* *Amer. Jour. Math.*, vol. xxiv, p. 158.

I, II, III, IV, V, in space, have appeared du ing the last year in the Kansas University Quarterly, Vol. X. The results contained in these papers prepare the way for a complete enumeration of all collineation groups in space. A paper containing a classified list of all Lie groups of collineations in three dimensions will be presented at the Evanston meeting of the American Mathematical Society, September 2 and 3. This list numbers over five hundred groups classified according to their types and classes under these types.

Miss Helen Brewster has undertaken a detailed study of the group of collineations leaving invariant a surface of the second order. This group was carefully investigated by Lie in his "*Theorie der Transformationsgruppen*," Band III. On pages 251-4 he gives a table of twenty-four sub-groups of the group G_6 (F). Miss Brewster has classified Lie's list according to the six types which enter into the group G_6 (F). She has also determined the structure of each sub-group, and indicated certain ones that contain singular transformations. This paper will also be presented at the Evanston meeting.

§ 7. Conclusion.

I have thus sketched for you in broad outlines a comprehensive theory of collineations and their Lie groups. To fill in all of the details is impossible, for such a task would expand this report of an hour into an extensive course of lectures running through one or more semesters of the usual college year. The march of the theory is along a highway as broad and straight as the traditional theological one "which leadeth to destruction;" but with this difference that few there be that walk therein, at least for the present. So straight and level is the path that the end can be seen almost from the beginning. There are few pitfalls or stumbling blocks in the way, and no roaring lions seeking whom they may devour.

The theory is complete in outlines, but many of the details have not yet been worked out. While much has been done much still remains to do. A large share of my own mathematical endeavor has been spent in laying the foundation

and rearing the walls of the superstructure. It is a self-imposed task, but one which I cannot rid myself of, if I would. However inviting other fields of mathematical study may be, I cannot desert my own. To this end was I born, so it seems, and for this came I into the world that a geometrical theory of collineations might be established and made so simple that it can be understood by Hilbert's "man on the street."

To accomplish such a task is well-nigh impossible, but to strive for it earnestly is possible to every man who has tasted of the scientific spirit and thus come to know that the striving is its own reward and that the measure of success or failure attained thereby is merely a by-product of the process.

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